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UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

STUDIES ON THE HANDLING OF FRESH MACKEREL

(Scomber scombrus)

RESEARCH REPORT No. 1

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Research Report No. 1

STUDIES ON THE HANDLING OF FRESH MACKEREL

(*Scomber scombrus*)

By

M. E. STANSBY and J. M. LEMON

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ABSTRACT

THE MACKEREL (*Scomber scombrus* Linnaeus) is one of the most important food fishes of the United States. In 1935 the mackerel fishery ranked eighth in volume and seventh in value among the food fisheries of this country. Owing to prevailing methods of handling and shipment, however, considerable difficulty has been experienced in disposing of the entire catch at a profit. Studies of this fishery were conducted as a basis for recommendations leading to increased distribution and popularity of mackerel, and improved handling methods are discussed in this report.

The fat content of mackerel varies with the season, from a minimum of approximately 2 percent in spring to a maximum of 20 percent or more late in summer and in fall. This variation is important in determining the food value of fish, since fat fish contain a considerably higher calorific food value.

Spoilage is much more complicated in mackerel than in many other species, owing to the usual high fat content. Mackerel can be kept in good condition much longer, however, if eviscerated and packed in finely crushed ice, rather than floated in the round in sea water that contains but little ice. For example, floated mackerel keep in good condition for only about 4 days, while those eviscerated and packed in crushed ice remain in edible condition for 7 to 10 days.

Marketing of the catch necessarily involves transportation, the cost of which is based upon gross weight. By shipping mackerel in crushed ice, rather than floating them in barrels, the net cost of transportation is greatly reduced.

STUDIES ON THE HANDLING OF FRESH MACKEREL

(*Scomber scombrus*)

By Maurice E. Stansby, *Assistant Technologist,* and James M. Lemon, *Technologist, Division of Fishery Industries, Fish and Wildlife Service*

CONTENTS

	Page
Introduction	1
The mackerel fishery	2
Extent of the industry	2
Fishing methods	2
Early procedure	3
Present procedure	4
Markets and distribution	5
Trends in the wholesale price of mackerel	7
Scope of the investigation	9
Variation of the oil content of mackerel	10
The problem of mackerel spoilage	12
Theoretical considerations	12
Decomposition of mackerel flesh	13
Decomposition of mackerel oil	15
Practical spoilage problems	16
Bruising and softening of the flesh	16
Red feed (*Calanus finmarchicus*)	16
Evaluating the general quality of mackerel	18
Factors contributing to quality	18
Keeping quality after purchase	18
Appearance and odor during preparation	19
Palatability	19
Tests for spoilage	20
Organoleptic tests	20
Evaluating the general quality of mackerel—Continued.	
Tests for protein decomposition	22
Electrometric test	22
Hydrogen sulfide test	23
Tests for oil decomposition	24
Studies on the keeping quality of fresh mackerel	26
General storage conditions	26
Effects of methods of packing for shipment	26
Effects of methods of dressing	30
Comparison of dressing procedures	30
Bacterial growth	35
Oil decomposition	38
Shrinkage of eviscerated fish	38
Influence of delay in dressing	39
Effect of size of fish upon spoilage rate	40
Discussion	41
General considerations	41
Shipping charges	43
Summary	43
Recommendations	44
Literature cited	45

INTRODUCTION

The mackerel (*Scomber scombrus* Linnaeus) ranks among the more important species of food fish landed in the United States and is taken principally in the waters of the New England and Middle Atlantic States. The greater portion of the catch is marketed fresh; the remainder being frozen, salted, or smoked. Although the mackerel is considered one of the choicest food fishes of this area, it is not subject to such wide fresh distribution as many of the other species. The

Figure 1.—Boston mackerel (*Scomber scombrus*).

Note.—The Research Reports of the Fish and Wildlife Service supersede the Investigational Reports (44) of the former Bureau of Fisheries, Technical Bulletins (711) of the former Bureau of Biological Survey under the Department of Agriculture, and Wildlife Research Bulletins (4) under the Department of the Interior. Figures in parentheses indicate last number published in each series.

In accordance with the President's Reorganization Plan No. II the Bureau of Fisheries was transferred from the Department of Commerce to the Department of the Interior on July 1, 1939; and by Reorganization Plan No. III it was merged with the Bureau of Biological Survey on June 30, 1940, to form the Fish and Wildlife Service.

reason for this has been attributed to greater difficulty in handling. Since it was believed that an investigation of the factors controlling mackerel spoilage might suggest means whereby improvement in keeping qualities could be effected, the Bureau of Fisheries made a study of this problem. The purpose of this report is to discuss the information obtained.

THE MACKEREL FISHERY

EXTENT OF THE INDUSTRY

The mackerel fishery supports one of the more important food-fish industries of the United States. In 1935, according to Fiedler (1936), the catch of Atlantic mackerel amounted to 65,086,000 pounds, valued at $1,342,000, ranked eighth in volume and seventh in value among the food fishes landed in this country, and fourth in volume and value among fishes landed on the Atlantic coast. Nearly 1,100 fishermen took part in the mackerel fishery in 1935. A total of 1,500 trips were made and approximately 100 vessels and boats were used.

Mackerel first appear in schools off the coast of New Jersey during April. The quantity of fish taken early in the season is quite small compared with the amount caught later, so that the price of the fish caught in the spring is usually quite high. As the season advances these fish appear farther north, being caught off New York and Boston, and later as far north as Newfoundland. The largest quantity of mackerel is taken during July, August, and September. After September the supply dwindles rapidly, a few being caught in late November and in some years in early December.[1] The fish then disappear until the following spring, when they reappear off New Jersey and the cycle is repeated.

FISHING METHODS

Very little is known about the earliest methods of catching mackerel. However, prior to 1700 a law was passed by the Colony of Massachusetts which prohibited the seining of these fish, and it may be assumed that the first methods probably involved some type of seine which was operated close to shore. Records also show that between 1815 and 1860 the mackerel fishery was essentially hook-and-line, although gill nets were introduced in some localities during that period.

About 1860 a notable advance was made in fishing methods applicable to those species which school during their migratory movements. This was the introduction of the purse seine. Since mackerel are schooling fish, the purse-seine method of fishing was rapidly adopted and soon superseded hook-and-line fishing. At the present time over 75 percent of the mackerel catch is taken in purse seines, about 7 percent in gill nets, and the remainder in traps.

A mackerel purse seine is usually about 250 fathoms long and 18 fathoms deep, with a small strengthened area in the upper center section which is called the "bunt." The net has a cork line attached to the upper edge to give it buoyancy and a weighted line with metal rings attached to the lower edge. A purse line of stout rope is rove through the metal rings.

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[1] In 1938 and 1939 a few mackerel were caught during January and February.

When fishing for mackerel the seine is carried in a seine boat which is towed behind the mackerel seiner. When a school of mackerel is sighted by the lookouts, who are stationed at the masthead of the seiner, the vessel is maneuvered into proper position and the seine boat is hauled alongside and made fast to a towing boom which extends outboard at right angles from the deck rail about opposite the foremast. A dory is then launched, one end of the seine taken aboard, and the seiner encircles the school—towing the seine boat from which the net is payed out. When the two ends of the net have been brought together and the purse line has been hauled in, the excess netting is pulled by hand into the seine boat until the fish are concentrated within the bunt. The seiner then maneuvers alongside the bunt section, the net is made fast alongside, and the fish are brought aboard by means of a large dip-net which is operated from the deck. Each time a school of fish is sighted the entire operation is repeated until a load has been obtained or it is necessary to return to port in order to land the fish while they are in good condition.

EARLY PROCEDURE

Though the methods of handling mackerel prior to 1815 are not definitely known, the fish were probably taken in small quantities near the shore and consumed fresh shortly thereafter. Between 1815 and 1820 the process of salting was greatly expanded, and until long after the use of ice was a firmly established practice the greater portion of the mackerel catch was salted. Previous to the adoption of ice the fish were usually salted at the time of catching, although increasing quantities were being landed fresh for subsequent salting. At present the market for fresh mackerel so far exceeds the demand for the salted product that the bulk of the catch is marketed fresh.

In preparing mackerel for salting during the early days, both aboard ship and on shore, the fish were first split and cleaned and then subjected to an operation known as "plowing." This consisted of producing cracks in the flesh near the backbone for the purpose of giving the fish the appearance of being fatter than was actually the case. The reason for this operation was the fact that as the season advanced and mackerel increased in fat content, cracks would normally appear in the flesh near the backbone when the fish were split. The depth of the cracks was roughly proportional to the fatness of the fish. In the early 1800's a fat fish was considered superior to a lean one, and plowing was a common practice for increasing the sales value of the fish. This is of interest since it indicates that even at this early date the industry recognized the varying degree of the fatness of mackerel; a condition which is often lost sight of today.

Between 1850 and 1870 two drastic changes were made in connection with the mackerel industry. It was during that period that ice was first used aboard fishing vessels, and the purse-seine method of fishing began to displace the old hook-and-line fishery. With fish being taken in greater numbers and with greater ease, and with facilities for preserving them with ice, it soon became less essential and probably impractical to depend upon the former procedure of salting the fish on board the fishing vessel. However, since vessels were still slow and several days might elapse before the fish were anded, it remained common practice to dress the fish at the time of catching. The dressing operation, which was termed "gibbing," consisted of removing the viscera and gills through the gill cleft without slitting the belly wall. The gibbed fish were then washed and packed with ice in small buckets. Such importance was placed on the value of gibbing as a means of retarding spoilage that the State of Massachusetts enacted a law which required that all mackerel be gibbed at sea if they were to be landed fresh. The dressed fish were ordinarily packed in ice in small kegs, to prevent bruising, and stowed in the hold of the vessel. When the fish were landed they were often held in what was termed "dry ice." This was ordinary water ice cut by hand into thin shavings with an ice shaver. Mackerel handled in the above manner from the time of catching could be kept in good condition for a considerable period.

PRESENT PROCEDURE

Since 1900 two important developments affecting the mackerel industry have taken place. All mackerel boats have been equipped with power engines, and improved transportation facilities now permit rapid delivery of mackerel to distant points. As a result of the decrease in time required for transportation from fishing grounds to consuming markets, the industry considers the gibbing of mackerel at sea as being no longer necessary, and, with the repeal of the Massachusetts law requiring this procedure, gibbing has been discontinued. Also, the practice of packing the fish in small individual containers has been discontinued in favor of gross storage with ice in the hold of the boat.

The fish-hold of a mackerel seiner is usually divided into compartments which are known as bins, or pens. Each bin is about 4 feet long, from 6 to 7 feet deep, and tapers from about 5 feet in width at the top to about 2 feet in width at the bottom; conforming generally to the shape of the hull of the vessel. Each bin will hold from 3,500 to 5,000 pounds of mackerel.

In stowing mackerel an initial layer of ice is first placed on the floor of the bin, a layer of fish is then permitted to drop down onto the ice through manholes in the deck above, another layer of ice is added, more mackerel, etc. Boards are usually placed across the bins at regular intervals in order to relieve the weight and pressure on the fish. When the bin has been loaded a final heavy layer of ice is placed on top to prevent the possibility of the upper layer of fish absorbing heat from the deck. The hatches are only opened for the time necessary to ice down the fish.

Usually 1 ton of ice crushed to pebble size, or slightly larger, is used in each bin of fish. This averages about 12 tons to care for 60,000 pounds of mackerel. Interviews with several vessel captains on the question of how much ice they thought necessary for certain amounts of mackerel resulted in the following figures:

Pounds of fish	*Tons of ice*
80,000	15
60,000	12
50,000	12
35,000	11
23,000	6

It is the custom of most of the fishermen to take on at least 10 tons of ice for a trip. Should the catch exceed expectations and insufficient ice is on hand, such ice is used as sparingly as the outside temperature and distance from market will permit. If the vessel is within half a day's journey from market and an extra large catch is made, holds are filled and the excess is loaded on deck—sometimes without ice.

An average mackerel-seiner trip covers a period of 3 days—1 day going out, 1 day fishing, and 1 day returning. There is much variability, however, and the fish might be landed when they are from 6 to 60 hours out of the water; the average time being 12 to 24 hours.

Upon arrival in port the mackerel are removed from the hold and hoisted to the wharf by means of wire baskets. There the fish are weighed and removed to the packing house for packing and shipment.

In packing fresh mackerel for shipment they are placed in watertight wooden barrels, known as "Irish" barrels, having a capacity of about 150 pounds of fish, 45 pounds of ice, and enough sea water to float the fish. The buoyancy given by the water prevents the fish from being bruised excessively during transit. Sea water is used in preference to fresh water in order to minimize leaching, which tends to cause fading of the natural color of the skin. The barrels are covered with squares of burlap having a waterproof coating on one side. This method of packing is commonly known as floating. Packing-house shipments are usually made to wholesale dealers in the larger marketing areas, and there the fish are repacked to fill individual orders received from retail dealers. The general practice in repacking small orders is to pack the fish in wooden boxes with sufficient shaved ice to keep them in good condition. In the preparation of large orders, however, most wholesalers find it more convenient to replace the sea water in the barrels with freshly drawn sea water or brine, add a fresh supply of ice, and make delivery to the retailer in the original barrels.

A survey of stores handling fresh mackerel has disclosed the fact that in most instances the fish are sold at retail from the containers in which they were received from the wholesaler, ice being added as necessary. Also, that the majority of retailers decline to stock more mackerel than can be sold in 2 or 3 days. The adoption of these practices has enabled the retailers to market fresh mackerel with a minimum of handling and in a uniformly good condition.

In preparing mackerel for the housewife the retailer usually splits the fish down the back. (See fig. 2.) This method has the disadvantage that when the fish is baked or broiled the hottest portion of the flame, which is usually at the center of the burner, is nearest to the thin section of the fish. Recently some of the fish dealers have been splitting mackerel from the belly toward the back. (See fig. 3.) This has the advantage of placing the thickest portion of the flesh near the hottest part of the flame and insures the flesh near the backbone of being thoroughly cooked before that at the edge has become scorched.

MARKETS AND DISTRIBUTION

In a normal year over 90 percent of the mackerel caught are landed in Massachusetts, and the remainder in Maine, New York, New Jersey, and Rhode Island. About half of the mackerel from the Massachusetts fleet are received at Boston, about one-fourth at Gloucester, and the remainder at Provincetown, New Bedford, and other ports.

Most of the mackerel landed at Gloucester are shipped by truck to Boston, New York, Philadelphia, and intermediate points. Mackerel landed at Boston, and not consumed locally, likewise are shipped by truck to nearby points and by express or freight to more distant cities such as Cleveland, Chicago, and Washington, D. C.

A very large portion of the mackerel catch is consumed in cities along the Atlantic seaboard between Philadelphia and Portland, and inland as far as Albany. Unfortunately no figures are available as to the exact geographical distribution of fresh mackerel. However

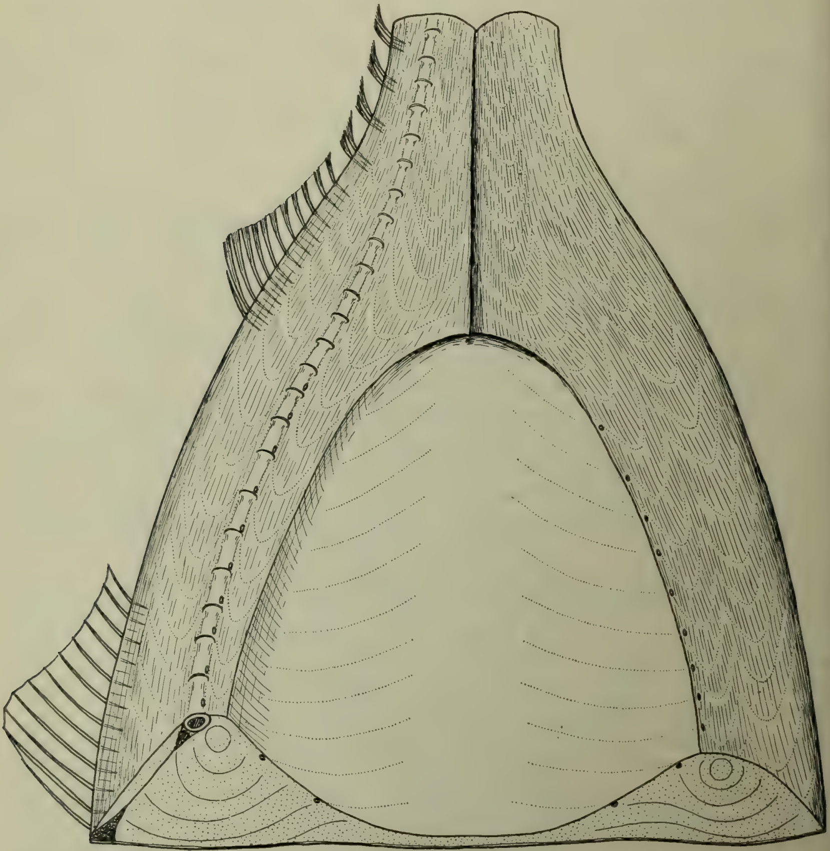


FIGURE 2.—Ordinary method of splitting mackerel which is to be broiled. In this method the thinnest portion of the fish will be subjected to the hottest part of the broiler.

the results of surveys made by Hopkinson (1921a; 1921b; 1921c; 1922a; 1922b), Fiedler (1927), and Fiedler and Matthews (1925), indicate that the common mackerel is not very well known in cities outside of the New England and Middle Atlantic Coast States. This was confirmed by one of the writers in a number of inland cities, including Cleveland, Chicago, St. Paul, and Minneapolis.

The relatively small quantities of fresh mackerel received in Cleveland and Chicago are consumed almost entirely by various foreign groups. In Minneapolis and St. Paul less than 10 percent of the mackerel receipts are sold fresh, the remainder being received frozen or salted. Apparently most of the fresh mackerel consumed in Midwestern cities is used by persons who have recently come to this country and who have been used to eating mackerel in their native countries. It is fairly certain that the average American west of the Appalachian Mountains does not include fresh Atlantic mackerel in his diet.

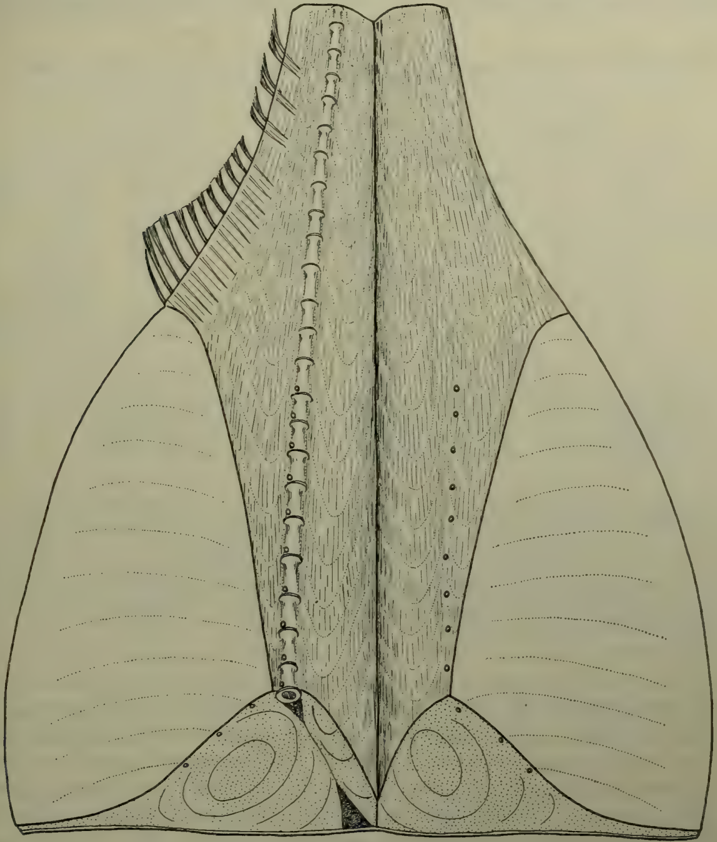


FIGURE 3.—Improved method of splitting mackerel which is to be broiled. In this method the thickest portion of the fish will be subjected to the hottest part of the broiler.

TRENDS IN THE WHOLESALE PRICE OF MACKEREL

During the past 20 years the average price paid to fishermen for mackerel has decreased approximately 75 percent. (See table 1.) In the period 1931–35 the average price of mackerel to the fishermen was 2.3 cents per pound, as compared with 9.6 cents for the years 1916–20. While many factors contribute to the establishment of the wholesale price of fish, making an exact determination of the cause of fluctuation from year to year impossible, the much greater decline in mackerel prices, as compared with other principal New England fish, is not without significance. Most fish fluctuate in quantity of catch and price per pound from year to year and there is a general correlation between these fluctuations; a large catch tending to lower the price, and vice versa. In the case of mackerel this correlation is much more pronounced, indicating that the value of mackerel to fishermen is more subject to the available supply than is the case with other species. For example, considerable fluctuations may occur in the catch of cod and haddock without causing violent fluctuations in prices.

TABLE 1.—*Trend in catch and price of mackerel, haddock, and cod* [1]

5-year period	Mackerel				Haddock				Cod			
	Average catch per year	Average price per pound [2]	Relation to period 1916–20		Average catch per year	Average price per pound [2]	Relation to period 1916–20		Average catch per year	Average price per pound [2]	Relation to period 1916–20	
			Catch	Price [2]			Catch	Price [2]			Catch	Price [2]
	Lbs.	*Cts.*	*Pct.*	*Pct.*	*Lbs.*	*Cts.*	*Pct.*	*Pct.*	*Lbs.*	*Cts.*	*Pct.*	*Pct.*
1916–20	24, 100, 000	9. 6	100	100	63, 500, 000	4. 3	100	100	52, 000, 000	4. 2	100	100
1921–25	26, 400, 000	7. 3	110	76	74, 500, 000	3. 1	117	70. 5	56, 800, 000	3. 2	109	76
1926–30	60, 600, 000	5. 2	252	54	154, 200, 000	3. 2	243	73	61, 400, 000	3. 4	118	81
1931–35	52, 800, 000	2. 3	219	24	175, 400, 000	2. 5	276	57	99, 700, 000	2. 1	192	51

[1] Data in table 1 were calculated from the following sources: In the case of mackerel for the period 1916–30 the statistics of Sette and Needler (1934) were used. This is the estimated total mackerel catch. For the period 1931–35, inclusive, the statistics for the total mackerel catch and value for the New England States were taken from Fishery Industries of the United States (Fiedler). For cod and haddock all data were taken from Fishery Industries of the United States. For the period 1916–30 the data used were for American fishing vessels which landed their catch at Boston and Gloucester, Mass. and Portland, Maine, and for the period 1931–35, in which such data had not been tabulated, the total catch for the New England States was used. The latter data were not available for all the years during the period 1916–30, which necessitated the use of data from a different source.

[2] Price to fishermen.

In the surveys conducted in fish markets in various cities by the Bureau of Fisheries in 1922 (previously cited) the results indicated that both haddock and mackerel were virtually unknown in inland cities. At that time a number of fish dealers attributed the lack of popularity of mackerel to its poor keeping quality. In 1936 the Bureau again conducted a survey as to the popularity of various species of fish in 61 cities in the United States (Johnson, 1938). The six most popular species were determined for each city. Data taken from the 1936 report (see table 2) show that in New England, where both mackerel and haddock are available in good condition at all times during season, the two species lead in popularity. However, in inland cities mackerel is no better known today than in 1922, while haddock has become one of the most popular species.

This great increase in the distribution of haddock since 1922 is undoubtedly due to the improved methods of handling this fish. In recent years the packaged fillet business has been greatly expanded both for fresh and frozen haddock, and this has led to a fish of much higher quality being placed on the market in cities far removed from the Atlantic seaboard. Accordingly, since mackerel is generally considered to be at least as choice a fish as haddock in cities where it is available in good condition, it would seem to follow that if better handling methods were adopted for this species a much wider distribution and a more stable price could be obtained.

Under present conditions if a large catch of mackerel is landed the surplus fish must either be absorbed by the market along the Atlantic seaboard or go into the freezers. Either alternative results in a disastrous lowering of prices, often to a point well below the cost of production. If a market was available in the Midwest, these surplus fish could be more readily disposed of without causing such drastic lowering of prices.

TABLE 2.—*Popularity of mackerel and haddock in various cities in 1936* [1]

New England States			Other States		
City	Order of preference		City	Order of preference	
	Mackerel	Haddock		Mackerel	Haddock
Boston, Mass.	2	1	Cleveland, Ohio	[2] 3	3
Fall River, Mass.	1	5	Dallas, Tex.		1
Manchester, N. H.	2	1	Denver, Colo.		4
New Haven, Conn.	2	3	Detroit, Mich.		5
Portland, Maine	2	3	El Paso, Tex.		2
Providence, R. I.	4	1	Kansas City, Mo.		1
			Milwaukee, Wis.		4
			New York, N. Y.	[3] 3	2
			Omaha, Nebr.		2
			St. Louis, Mo.		2
			St. Paul, Minn.		2
			Washington, D. C.	[2] 6	5
			Wichita, Kans.		2

[1] Johnson, 1938. [2] During June. [3] During May and June.

SCOPE OF THE INVESTIGATION

The original intent of this investigation was to determine whether or not the handling of fresh mackerel could be so improved as to reduce losses incurred by spoilage and permit a wider range of distribution. Consideration of the present methods used in handling this fish indicated that a number of relatively simple changes might lead to a considerable improvement in keeping quality. It was believed that the custom of floating the fish in sea water during transportation is especially harmful to the fish, particularly if the sea water is badly contaminated with bacteria. It also was believed that if the fish were eviscerated, rather than left in the round, the fish would keep in a much better condition for a longer period of time. As a result of these observations a series of experiments was begun to ascertain the optimum handling conditions for mackerel. It was soon realized that there were many complicating factors which had not been foreseen, and that these would have to be dealt with before the study originally started could be completed.

Early in this work it was realized that the composition of individual mackerel varies to a considerable extent. This difference is largely one of the oil content, or fat, which shows a surprisingly large variation. These variations were found to be influenced by a number of factors, chief of which was the season of the year in which the fish were caught. While the general trend of this seasonal variation of the oil content of mackerel has been known for a long time, no quantitative information as to the exact oil content of the fish at different seasons could be found. Mackerel which first appear off the Atlantic coast in early spring are very lean and as the season advances they become fatter and more oily, reaching a maximum in August, but no figures could be found to give any indications as to the amount of this variation. Consequently, a study was made of the variation in the oil content of mackerel.

It was found that the spoilage of mackerel was a much more complicated process than that of nonfatty fish. While limited information was available as to the chemistry of the decomposition of fish protein, little could be found bearing on the decomposition of fish oil while still present in the flesh. Since mackerel is a very oily species, a series of experiments was begun to determine the course of decomposition under different conditions of storage.

It was also found necessary to develop methods for determining the relative freshness of mackerel. These include tests for decomposition of both the protein and the oil. With all these facts and methods available, it was possible to store fresh mackerel under varying conditions, and, by following the course of spoilage, to determine the best handling conditions.

VARIATION OF THE OIL CONTENT OF MACKEREL

Very little reliable information has been available as to the oil content of mackerel. This is surprising, since the variation in the oil content of this fish is greater than for most other species. The most comprehensive analyses of American food fishes are those of Atwater (1888), who analyzed many different species for the various constituents, including oil, and reported in the case of mackerel an oil content varying from 2.9 to 7.7 percent, the average being 7.1 percent, which has been widely quoted. However, the data upon which these figures were based were obtained from fish caught either in the spring or late fall, at which times the oil content is at a minimum.

Table 3.—*Oil content of mackerel of various sizes*

Length of fish[1] (centimeters)	Probable age group[2]	Average oil content		
		June 5	Oct. 20	Nov. 17
	Years	*Percent*	*Percent*	*Percent*
30–31½	1		14.6	9.4
31½–36½	2	9.3	13.6	22.0
36½–38	3	7.0	16.5	20.1
39–42	5 and 6	4.0	17.1	16.5
41–44	7 and over	2.2		

[1] Measurements were made by Frank E. Firth, Cambridge, Mass.
[2] Information as to age groups was supplied by O. E. Sette, Cambridge, Mass.

The present work was confined largely to a determination of the seasonal variation in oil content. A considerable variation is also due to difference in size or age of the fish. Enough work was done to show that this is the case, but not sufficient to draw any definite conclusions. These results (see table 3) indicate that small fish show less variation in oil content with the season than larger ones. However, this cannot be taken as entirely conclusive until more data are obtained.

In order to minimize the effect of size, samples were taken comprising small, medium, and large fish. The samples were usually obtained directly from the fishing boats as they landed in Gloucester. The mackerel caught in early spring, which are never landed in New England, were shipped in from Cape May, N. J. All samples reported were obtained during a single season.

While there is undoubtedly some fluctuation in oil content from year to year at the same season, it is apt to be small and the general trend should be uniform. This was confirmed by making a few analyses during three other seasons, although one exception was noted with mackerel caught in the late fall. These fish seem to vary considerably both between different lots of fish caught in the same year, and from year to year. In some cases mackerel caught in November contained as high as 20 percent oil, while in other cases a marked decline was shown from the maximum attained during the summer.

In making the analyses fillets were cut from the fish, removing as many bones as possible. The skin was then removed, care being taken to lose as little as possible of the oil occurring next to the skin. In some cases the fish were analyzed separately to show the difference in oil content between individuals, while in other cases the fish were ground together and a single average analysis made. From 4 to 25 fish were used for each sample.

The method of analysis used was one developed especially for this work which allowed a rapid, yet reasonably accurate determination of oil. The method has been described in detail by Stansby and Lemon (1937) and will not be repeated here. The results obtained in 11 lots of fish examined are given in table 4.

TABLE 4.—*Variation in oil content of mackerel with the season*

Date fish were caught	Number of fish analyzed	Maximum oil content	Minimum oil content	Average oil content
		Percent	*Percent*	*Percent*
Apr. 18	[1] 13	----------	----------	3.9
22	8	7.6	2.7	4.8
May 3	[1] 4	----------	----------	8.0
21	[1] 4	----------	----------	9.0
June 1	[1] 6	----------	----------	9.8
July 23	13	17.3	6.1	10.6
Aug. 13	7	25.6	10.6	17.5
15	7	21.6	16.0	19.2
Sept. 11	20	11.4	2.0	6.5
Oct. 1	25	16.2	3.0	10.1
Nov. 17	12	15.2	2.2	8.2

[1] These fish were analyzed as a composite sample.

With a single exception the mackerel examined showed a regular increase in oil content from a minimum average value of 3.9 percent in April to a maximum average value of 19.2 percent during August, followed by a decrease in oil content to an average minimum value of 8.2 percent in November. Since mackerel are not usually caught during the winter months, no values are available for that season. A large deviation between individual fish of the same lot also was observed. Thus, fish caught in April varied between 2.7 and 7.6 percent; those caught in August, between 10.6 and 25.6 percent; while mackerel caught in November showed the largest deviation of all, 2.2 to 15.2 percent, a difference of almost 7 times. These data, therefore, indicate a much higher oil content for mackerel than is generally believed to be present. Bodansky (1934), Leach and Winton (1920), and Sherman (1932), all list mackerel in their food charts as having an oil content of 7.1 percent, a value apparently obtained from the analysis of Atwater (1888).

Not only is the oil content of mackerel generally understated but also the calorific value is widely quoted as 630 calories per pound of flesh. This value would now appear to be too low; the true value varying from about 500 calories per pound of flesh for lean fish caught in the spring to 1,350 calories per pound for very fat fish caught in the summer, with a value of about 900 calories per pound of flesh being fairly representative for the bulk of the catch.

The effect of the seasonal variation upon the energy value expressed in calories is shown in figure 4. These values were calculated, assuming 4 calories per gram of protein and 9 calories per gram of fat The protein content was taken as 18 percent in all cases. The energy value of mackerel may vary by more than 3 times in extreme cases, and 1 pound of average mackerel flesh from a fish caught in August will yield more than twice as many calories as 1 pound of mackerel flesh from a fish caught in April.

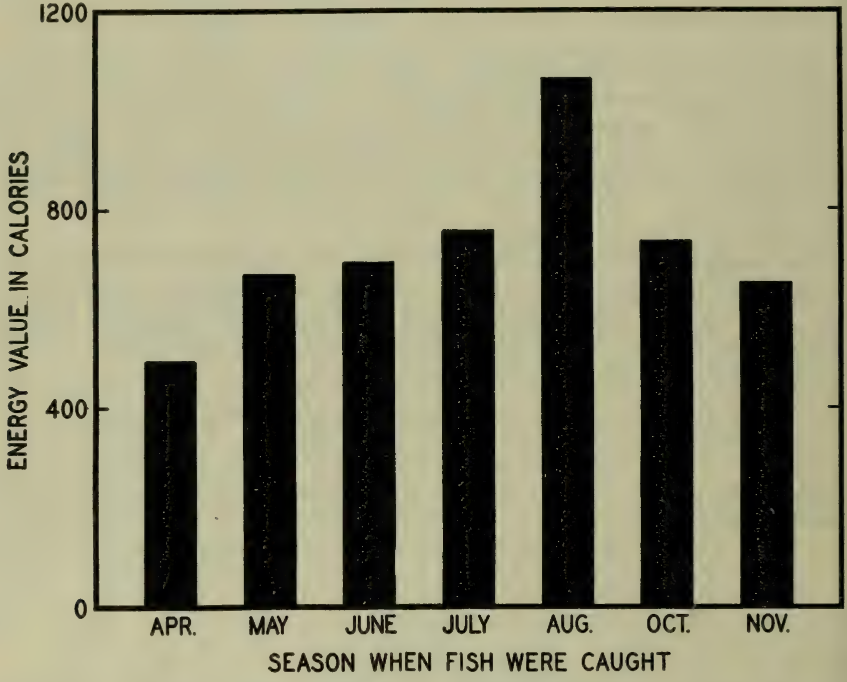


FIGURE 4.—Energy values, expressed in calories per pound of fresh fish, for mackerel caught at various seasons.

THE PROBLEM OF MACKEREL SPOILAGE

THEORETICAL CONSIDERATIONS

Mackerel flesh may be considered to consist of three principal components—light muscle tissue, dark muscle tissue, and oil. The dark muscle occurs chiefly in layers between the skin and the light muscle. The oil is intermixed throughout the flesh but is not uniformly distributed about the body, the tendency being for a considerable portion to be near the surface, especially in those individuals caught during the summer months and having the highest oil content. The flesh, especially the light portion, is usually soft. This property is often accentuated by the presence of considerable oil which makes the texture semiliquid. The oil is semidrying, having an iodine number of about 167. When fresh the oil is colorless and possesses a sweet, slightly fishy odor and flavor.

DECOMPOSITION OF MACKEREL FLESH

The protein of mackerel, as with other species of fish, is decomposed by the action of bacteria as well as enzymes. Owing to the fact that this species is handled in the round, the action of enzymes is of more importance than with species from which the viscera is removed at the time the fish are caught.

Immediately after the death of the fish rigor mortis sets in. While this phenomenon is often thought of as a mere stiffening of the fish, it actually includes various other changes. During life and before rigor begins a portion of the water in the flesh can be separated from the protein by exerting a slight pressure. When rigor mortis is present, however, the water and protein "set" in a gel-like consistency from which very little water can be removed, even when the flesh is subjected to enormous pressures. Simultaneously considerable lactic acid develops which increases the acidity of the flesh to a noticeable extent. Several other phenomena occur also, such as the shortening of the muscle fibers and increases in buffer capacity, etc. These, however, have no bearing on the spoilage of the fish—so far as our present knowledge indicates.

The changes occurring during rigor mortis have a tendency to prevent, or at least minimize, bacterial action upon the flesh. The gel-like consistency of the flesh is considerably more difficult for the bacteria to penetrate than is the semiliquid condition of the flesh immediately before or after rigor mortis. The growth and action of the bacteria are also probably retarded by the increase in acidity occurring during rigor mortis. Thus, the presence of rigor mortis is not only a guaranty that the fish is in first-class condition but it also acts as a natural protection against bacterial invasion and decomposition. As long as full rigor is present, practically no bacterial decomposition can take place.

During life many natural functions, especially those associated with metabolism, depend upon the presence of various enzymes in the body. After death these enzymes begin to tear down the complex body tissue into simpler compounds. Most of the compounds so formed are harmless in themselves but cause the fish to deteriorate in quality, owing to the softening of the flesh and the fact that fish in such condition are a more ready prey to the action of bacteria. This process is known as autolysis. It can be retarded by keeping the temperature of the fish as low as possible, but even at freezing temperatures autolysis proceeds slowly.

In the case of fish handled in the round, the enzymes of the body tissues are further accompanied by those present in the visceral organs. The stomach, pyloric caeca, and other organs contain a number of enzymes for digesting the food which is eaten, and after death these enzymes break down the surrounding tissues with extreme rapidity. While bad flavors or odors do not usually accompany this early stage of autolysis, it is undesirable because it detracts from the appearance of the fish.

The beginning of autolysis and the decrease of rigor mortis overlap, and it is a disputed point as to whether the onset of autolysis causes the disappearance of rigor, or whether the disappearance of rigor allows autolysis to begin. The former view appears to be better founded, according to the experience of the writers, because occasionally fish in maximum rigor were found to show signs of extensive autolysis, especially where the tissue enzymes were supplemented by those of the viscera.

Shortly after autolysis is under way, and rigor mortis has disappeared, bacterial decomposition of the fish commences. The first stage in the bacterial decomposition is usually a further break-down of the protein. Bacteria, however, do not stop at the formation of intermediate compounds but continue to decompose these compounds into still simpler ones.

The most frequently formed end product is probably ammonia, but various other nitrogen compounds, such as amines, are often found simultaneously in the early stages of decomposition. The evolution of ammonia is very slow at first, so that the resulting odor is not objectionable, and, being mixed with other substances, is often not even recognized as such. In advanced stages of decomposition, however, comparatively large quantities of ammonia are given off and the sharp, penetrating odor is easily discernible.

Fish protein contains cystine and other amino acids which have sulfur as one of their constituents. During bacterial decomposition hydrogen sulfide is evolved. Ordinarily the quantity liberated is so small that its effect upon the odor of the fish is not pronounced until an advanced stage of spoilage is reached. In the handling of mackerel the fish are kept under water, and, since air cannot reach them, a condition is maintained which is favorable to the growth of anaerobic bacteria which generally promote the formation of hydrogen sulfide. Furthermore, the skin of the mackerel is more or less impervious to gases and helps to retain the gaseous hydrogen sulfide. It is often observed that immediately upon cutting open a fish a strong odor of hydrogen sulfide is evident. After only a few seconds most of the gas escapes and this odor is considerably reduced. The presence of hydrogen sulfide in fish gives it a very bad odor which is ordinarily much worse than that of ammonia and similar compounds. Consequently every effort should be made to avoid its formation.

Although most of the nitrogen in fish occurs as protein, a small part is present in other compounds. Among these may be mentioned various free amino acids, lecethin, and trimethylamine oxide. The free amino acids may be expected to decompose and contribute to spoilage in a manner similar to the protein. Trimethylamine oxide is not usually decomposed by the action of enzymes, but it is readily attacked by bacteria. It is of especial interest since it readily breaks down into trimethylamine, which is one of the compounds principally responsible for the odor of stale fish, and although trimethylamine oxide occurs in rather minute quantities in fish, it may be of considerable importance in contributing to spoilage.

DECOMPOSITION OF MACKEREL OIL

An entirely different type of fish spoilage is involved in changes in the oil. As has previously been stated, mackerel is an extremely oily fish in which the oil content may be as high as 25 percent or more. When this is the case the amount of oil exceeds that of every other constituent of the fish except water, and consequently deterioration of the oil is of considerable importance. As with the protein, the oil is decomposed by bacteria and enzymes although it can decompose spontaneously without the aid of either. Decomposition occurs chiefly in two ways. The first type of change results in splitting the oil into glycerine and fatty acids, and is called hydrolysis. The second change involves the oxidation of the oil with the resultant formation of numerous products which lead to rancid flavors and odors. Hydrolysis is usually accelerated by the presence of either bacteria or enzymes. Oxidation may be hastened by the presence of suitable enzymes but it is less influenced by bacteria.

Hydrolysis of oil tends to give it a bitter flavor which is probably caused by the presence of the acids formed. The odor of the oil remains practically unchanged so long as hydrolysis is the only reaction occurring. Even the development of the somewhat bitter flavor is rather slow, so that this type of change is not very serious except in extreme cases.

Oxidation is the more important type of change occurring in mackerel oil and deserves primary consideration. Fish oils as a class are of the type chemically known as unsaturated. This indicates that such oils can combine with considerable quantities of oxygen from the air. A familiar example of the oxidation of an oil is the drying of paints or varnishes. In this case the hard external coating which forms upon standing is due to the addition of oxygen from the air to the oil in the varnish. Similarly, mackerel oil when exposed to the air combines with the oxygen and changes from a clear, thin liquid to a viscous mass—in extreme cases even becoming solid. In fact, owing to its high degree of unsaturation, mackerel oil is sometimes used in the manufacture of paint. As the oil becomes more and more viscous the color changes progressively from almost colorless through various stages of yellow to an orange brown. Simultaneously the flavor, and to a less extent the odor, of the oil develops the characteristics of rancidity.

Fresh mackerel oil has a sweet odor and flavor which leaves an oily sensation, but little or no aftertaste, when eaten. As rancidity develops, the oily sensation evident after eating is accompanied by a sharp, rather unpleasant flavor which persists for a considerable period. As rancidity increases this aftertaste becomes more and more unpleasant, and in advanced stages of rancidity it may endure for an hour or more after the oil has been tasted. When these rancid flavors are mixed with the flavors of the fish protein they become difficult to recognize with certainty, but owing to the persistent aftertaste of the oil they can readily be detected long after the protein flavor has disappeared.

Rancidity is of less importance in fresh mackerel than in the salted or frozen product. In many cases no rancidity is evident before the fish is eaten. The relative importance of rancidity in the spoilage of mackerel is dependent upon a number of factors. Thus, in fish which have a very low oil content, rancidity plays a small role in the spoilage of the product; whereas in fish containing 20 to 30 percent oil a very definite rancid aftertaste may develop before the fish is completely inedible.

The layer of oil next to the skin of the mackerel becomes rancid much sooner than that contained in the deeper portions of the flesh. The closer the oil is to the surface the more ready access it has to the oxygen in the air. Very little oxygen penetrates to the center of the fish so that oil in the interior of the flesh remains fresh for a much longer period of time than that near the surface. When mackerel containing rancid oil is eaten, not only is a persistent aftertaste left in the mouth but many people complain of what is termed "repeating of the mackerel." For many hours the flavor of the mackerel oil is tasted at intervals, indicating that digestion was not complete. It has been found that if the skin is removed before cooking, little trouble will be experienced with the so-called repeating. This is due to the fact that when the skin is removed most of the outer layer of oil adhering to the skin is also discarded. Since it is this outer layer of oil which contains most of the rancid products, the remainder of the oil in the fish is comparatively fresh.

PRACTICAL SPOILAGE PROBLEMS

BRUISING AND SOFTENING OF FLESH

As previously indicated, the flesh of the mackerel is exceedingly delicate and special care should be exercised in handling in order to avoid bruising it. The protein in the flesh is not only softer than that of most other fish but the presence of considerable oil also adds to its delicate nature.

Fish handled in the round normally soften more rapidly on account of the greater enzyme and bacterial activity of the viscera in contact with the flesh of the body cavity. The belly wall may become softened to such an extent that jostling the fish is apt to cause a break in the skin and expose the viscera. When this occurs the fish are unsuitable for sale because of their unsightly appearance.

If the fish are packed with large pieces of ice, the corners of the ice frequently break through the skin or leave marks on the surface. The fish also become generally softer the more handling they undergo.

The development of bruises and softness in fish is undesirable for two reasons: First, a soft fish is considered to be of inferior quality and many consumers use the degree of softness as an index to the quality of the fish, and the second and more serious result is that when fish have been bruised the flesh is more readily decomposed by enzymes and thus made more susceptible to bacterial action. Also, since the spoilage rate of fish is influenced by the number of bacteria present, any skin abrasions lead to greater bacterial contaminations of the flesh and a further acceleration of decomposition.

RED FEED (*CALANUS FINMARCHICUS*)

Mackerel feed largely upon minute crustaceans, one of the most common of which is *Calanus finmarchicus*. This crustacean often occurs in vast swarms and is called red feed by the fishermen because of its reddish-orange appearance. It is the contention of those engaged in the handling of mackerel that fish which contain large quantities of the red feed do not keep as well as those in which it is absent. Observations of the writers bear out this contention and indicate that spoilage of two types accompanies the presence of considerable quantities of the red feed.

The first type is apparently an extremely rapid autolysis. Only a few hours after the fish are caught the flesh around the backbone softens. After about 24 hours the flesh is entirely broken down in this region so that upon dressing the fish the bones are exposed free of flesh. Frequently mackerel containing much red feed exhibited more evidence of autolysis near the backbone only 24 hours after catching than other mackerel which did not contain red feed and which had been kept in ice for more than 2 weeks. It should be emphasized that it is not only the presence of red feed which determines the rate of autolysis, but the amount as well. Fish which contain small amounts of the red feed have been examined and found to exhibit but slight autolysis.

The second type of spoilage accompanying the presence of red feed is a rapid evolution of hydrogen sulfide from the flesh. Even freshly caught mackerel which contain much red feed give off a perceptible hydrogen sulfide odor from the flesh when first cut open. This odor does not persist for long, however, as would be the case of a fish in which extensive decomposition had taken place. An hour or so after the fish has been cut open no hydrogen sulfide odor is evident. Also, if the fish containing red feed, which give off hydrogen sulfide immediately after catching, are packed in ice for several days the odor of hydrogen sulfide is not nearly so strong as it was in the freshly caught fish.

There are numerous other organisms of a reddish appearance upon which mackerel feed which are not the true red feed. Fish containing large quantities of these other varieties do not decompose more rapidly than fish which contain little or no food at all. The true red feed can usually be distinguished by the orange color it possesses. The other types are usually dark red or purple in color.

Another feature of the presence of red feed which is very objectionable to those who handle the fish is that such fish are said to "burn" the hands. Persons who handle such mackerel are troubled with a skin irritation which leaves small lesions upon the hands. These lesions are blamed upon the red feed in the fish. Owing to this phenomenon, red feed is sometimes termed cayenne, or red pepper. However, the writers believe this trouble is caused by bacteria present around the boats and fish wharves, which is quite independent of the red feed itself.

A number of explanations can be given for the effect of red feed on the spoilage of fish. Not enough information is available, however, to decide which theory is most likely to be correct, and there probably is a combination of several conditions which bring about the total effect. The rapid autolysis occurring when red feed is present is usually accompanied by a large evolution of hydrogen sulfide which in some cases acts as a catalyst, increasing autolytic action of enzymes. It is possible that the marked degree of autolysis accompanying the presence of red feed is due to an activation by the hydrogen sulfide of the enzymes already present in the fish.

Red feed consumes prodigious amounts of bacteria; in fact it cannot live in their absence. Therefore, fish containing much red feed would likewise contain many bacteria, some of which might be capable of producing hydrogen sulfide. Another explanation is that red feed itself contains enzymes capable of producing the rapid autolysis observed. Bond (1934) has shown that *Calanus finmarchicus* contains a protein-splitting enzyme.

Unfortunately the only remedy known for reducing the spoilage blamed upon red feed in mackerel is applicable to only a small portion of the mackerel catch. When mackerel are caught in traps it is customary for the fishermen to examine the fish to see whether they contain these organisms. If they do, the fish are left in the traps for from 24 to 48 hours. After this time the intestinal tract is usually cleared and no further trouble of this nature is experienced. However, only a very small percentage of the mackerel caught on the Atlantic coast are taken in traps, so that this method of examination and elimination of the undesirable red feed is not usually available to Atlantic coast mackerel fishermen.

EVALUATING THE GENERAL QUALITY OF MACKEREL

FACTORS CONTRIBUTING TO QUALITY

The buyer is willing to pay more for fish of high quality than for a low-quality product. For this reason it is advisable to consider the factors which influence quality and to determine which are of most importance. The housewife uses such indications as clear eyes, bright-red gills, etc., as criteria of first-quality fish. These factors, which are of no consequence in themselves, indicate that certain other conditions are apt to be present. The properties which actually mean most to the consumer are keeping quality after purchase, good appearance and odor during preparation, and palatability.

KEEPING QUALITY AFTER PURCHASE

If fish is purchased for immediate consumption the keeping quality need not be given as much consideration as when it is expected to hold it over for a day or two before cooking. However, fish are frequently purchased in the morning and placed in the household refrigerator until evening, or the following day. Prior to sale the fish was kept in crushed ice at a temperature not much above 32° F. When removed from the ice for delivery the temperature of the fish immediately rises, since no attempt is made to refrigerate it during the delivery period. In warm weather the temperature of the fish will rise considerably during this time. If the fish is not cooked immediately upon receipt from the market it is usually placed in a household refrigerator where the temperature is probably not very far below 50° F.; a temperature considerably above that at which it had previously been stored.

The spoilage rate of fish is dependent upon a number of factors, one of the most important of which is the temperature of storage. This rate increases greatly with increasing temperatures, and, according to Hess (1934), the rate of decomposition of fish stored at 41° to 50° F. (temperature of refrigerator) is over four times as great as fish stored at 32° to 41° F. (temperature of fish stored in ice). Consequently, when fish is purchased at a store and carried home and placed in a refrigerator, decomposition proceeds at a greatly increased rate. For example, a fish which would remain in good condition for 36 additional hours if kept in ice at the retail store would keep only about 9 hours in a refrigerator in the home. Thus the keeping quality of the fish after sale to the consumer is of considerable importance, since it is not so much the condition of the fish when purchased, but the condition of the fish several hours later which is of most importance.

APPEARANCE AND ODOR DURING PREPARATION

A fish of high quality must have an appetizing appearance, especially during preparation. Even though the fish meets all of the requirements of palatability, if the flesh shows evidence of decomposition the person who prepares the fish will not find it as desirable as though it had been perfectly sound.

Of even more importance is the presence or absence of decomposition odors during preparation and cooking of the fish. Many fish give off a stale or putrid odor during cooking, yet have no bad odor or flavor when eaten. In such a case all of the bad odors have been driven off during the cooking. When it is ready for serving, however, no one present during the cooking has any appetite for the fish. Furthermore, the odor of stale fish may remain about the house for hours, if not days. Many people are under the impression that such a condition is always encountered with all fish, whereas only fish of inferior quality give off bad odors when cooked.

PALATABILITY

Palatability is determined by numerous factors which can be listed as follows, the order being according to relative importance:

1. Freedom from decomposition odors and flavors.
2. Freedom from aftertaste.
3. Presence of normal flavors and odors.
4. Correct texture of fish.
5. Good appearance of cooked fish.

Anyone can distinguish fish having a stale odor, and it is at once classified as being of inferior quality. What is not so generally recognized is that when an aftertaste is left in the mouth after eating the fish, it was of low quality. Many people suppose that all fish can be tasted after it has been eaten. This is not true, since an aftertaste usually is due to rancid oil in the fish.

Even though no decomposition flavors or odors are present, the flavor of the fish may not be satisfactory. Each species of fish contains various aromatic substances which give that species its characteristic flavor and odor. Moreover, fish contain numerous mineral substances which not only contribute to the flavor but add considerably to its nutritive value. When fish are not handled properly a portion of these substances may be lost, and such fish are not of high quality.

Various abnormal textures are sometimes observed when fish is eaten. Sometimes a portion of fish is described as stringy, another as rubbery, or another as tough. While these differences are often due to improper methods of cooking, they are also caused by the fish being improperly handled.

TESTS FOR SPOILAGE

With some species of fish, for example haddock, spoilage is a comparatively simple process. In such fish there is practically no oil present and they almost invariably decompose in the same manner, giving ammonia and amines as the chief end products. When such simple types of spoilage occur one or more chemical tests often can be correlated with the decomposition, and these tests normally will be more accurate than organoleptic tests because errors due to the personal equation are eliminated. Where more complicated decomposition occurs, however, scientific tests are much less reliable because an accurate correlation between the chemical tests and the degree of spoilage is complicated by the numerous factors which have to be considered. Therefore, in the case of mackerel, organoleptic tests are more important than scientific tests.

ORGANOLEPTIC TESTS

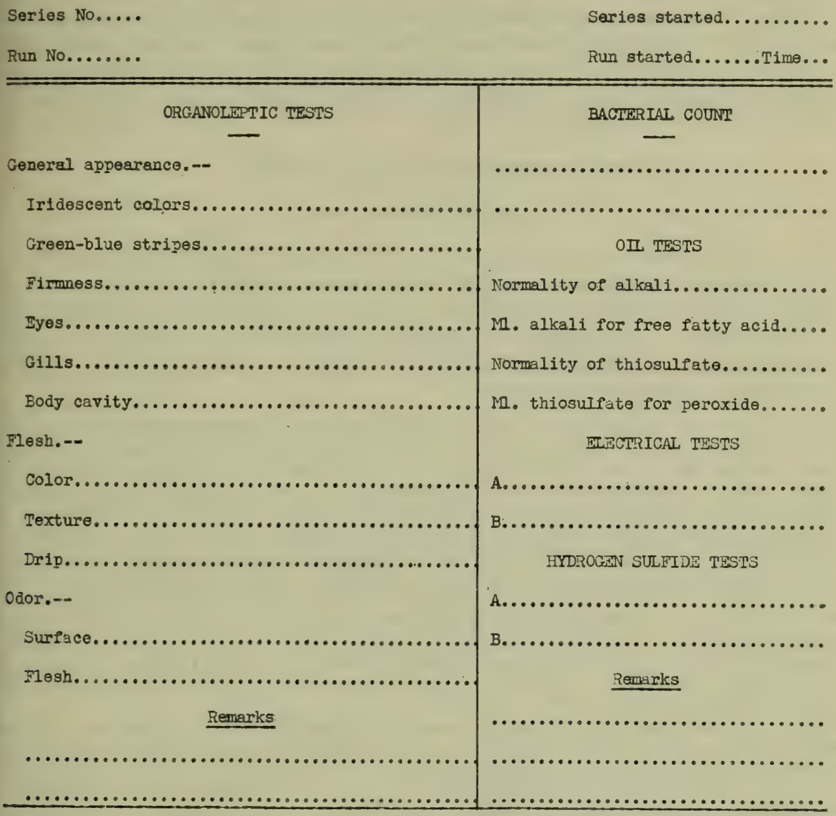
The organoleptic tests for judging the quality of fish are based on observations relating to the appearance, odor, texture, etc., of the sample in question. No single observation can suffice by itself, however, and final judgment must be based on the fitting together of a relatively large number of properties. The following points have received consideration during this investigation:

1. Observations on round fish.
    - (*a*) Appearance—"pearlescent" color, color of stripes, appearance of eyes and gills.
    - (*b*) Firmness—rigor mortis, softening of flesh.
    - (*c*) Odor of fish and gills.
2. Observations during dressing.
    - (*a*) Appearance of flesh near backbone, yellow gloss of flesh near viscera, and viscera.
    - (*b*) Odors—permanent odors and odors which do not persist.
    - (*c*) Condition of flesh—color, texture, and odor.
3. Observations on cooked fish.
    - (*a*) Appearance.
    - (*b*) Texture.
    - (*c*) Odor—during and after cooking.
    - (*d*) Flavor of flesh and oil.

In making the various organoleptic tests it was found to be helpful to have a blank form upon which all of the observations could be noted. In this way there was less chance of omitting or overlooking any particular test. An example of the type of form used in the present study is shown in figure 5. This form also includes space for the scientific tests which will be discussed later.

It will be appreciated that in making a large number of observations, many of which are limited in scope, it is essential that some manner of evaluation be used. After observations had been made on a large number of fish in varying degrees of decomposition, and after due consideration had been given to the limitations of the various tests, the following arbitrary method of evaluating quality, based on organoleptic examination, was adopted for the actual experimental work.

It was decided that 30 percent of the rating should be attributed to appearance. This included color of stripes, condition of eyes and gills, and the rigidity or firmness of the flesh. Fifteen percent of the rating was assigned to the condition of the body cavity, 10 percent to the texture of the flesh, and 45 percent to the various tests for odors. A fish considered to be excellent in all the factors contributing to appearance, condition of body cavity, texture of flesh and odor would be rated 100 percent.



Series No..... Series started..........

Run No........ Run started.......Time...

ORGANOLEPTIC TESTS	BACTERIAL COUNT
General appearance.--	....
Iridescent colors..............................	....
Green-blue stripes............................	OIL TESTS
Firmness......................................	Normality of alkali................
Eyes..	Ml. alkali for free fatty acid.....
Gills...	Normality of thiosulfate...........
Body cavity...................................	Ml. thiosulfate for peroxide.......
Flesh.--	ELECTRICAL TESTS
Color...	A..................................
Texture.......................................	B..................................
Drip..	HYDROGEN SULFIDE TESTS
Odor.--	A..................................
Surface.......................................	B..................................
Flesh...	Remarks
Remarks	....
....	....
....	....

Figure 5.—Data sheet used for recording results of organoleptic and scientific tests of mackerel.

Six different classifications were selected for each type of rating. These were excellent, very good, good, fair, poor, and very poor; each decreasing one-fifth of the percentage rating in the order given. Thus, a fish having the necessary qualifications as to color of stripes, condition of eyes and gills, and rigidity and firmness, to be considered excellent, would be credited 30 points; very good, 24 points; good, 18 points; fair, 12 points; etc. However, for purpose of presentation, it was believed the reader could detect differences better by some graphical method. Therefore, in tables 7, 10, 11, 15, 19, and 20, excellent will be denoted by XXXXX, very good by XXXX, good XXX, fair XX, poor X, and very poor by 0; in which X is equivalent to one-fifth of the total rating. Under the heading of appearance X will have a weight of 6; under condition of body cavity, 3; under texture of flesh, 2; and under odor, 9.

The above method proved most useful since it not only permitted a rather definite rating of a sample at any particular time but also made it possible to obtain a rather definite idea of the time required to reach a similar condition of quality under different methods of handling.

As previously indicated, organoleptic tests, up to the present time at least, are most suitable in following the spoilage of mackerel. So many different types of spoilage may occur that numerous scientific tests would have to be made before arriving at even the approximate condition of the fish. However, such tests are useful when used in conjuntion with organoleptic tests.

TESTS FOR PROTEIN DECOMPOSITION

ELECTROMETRIC TEST

An electrometric method for the determination of fish freshness has been described by Stansby and Lemon (1933). This method, originally described for haddock, has been extended to include cod and pollock. Many tests were also run using mackerel, but the results obtained were not as reliable as with the other species. A brief description of this test follows:

> Fish flesh has the ability to combine with acids to a degree varying with the degree of freshness of the fish. In the case of haddock this acid-combining power rises sharply after death of the fish, ordinarily reaching a maximum within 36 hours. It then declines slowly to a minimum of about one-half of the maximum value. Since haddock are rarely landed before they are at least 36 hours out of the water, the initial rise of the acid-combining power of the fish flesh can be disregarded for all practical purposes. The acid-combining power can be expressed as the A value, an arbitrary unit which is directly proportional to the amount of acid combining with the flesh. In the case of haddock the A value rises from about 25 at the death of the fish to a maximum of approximately 32, whereupon, as decomposition sets in, it falls to a minimum of 15, or in extreme cases 12. The fall in the A value proceeds simultaneously with what is known as primary decomposition; i. e., hydrolysis of the protein to simpler, though usually harmless compounds.
>
> In order to determine the acid-combining power of the fish flesh, a weighed sample of the ground flesh is shaken with water, and acid is added to bring the acidity of the suspension to a pH value of 6. The amount of acid required to bring the pH to 4.3 is then determined. The latter amount of acid, calculated according to certain empirical rules, is the A value. The first step, the addition of acid to pH 6, gives another value which varies with fish spoilage. The amount of acid used in this stage is called the B value and is more or less proportional to the development of secondary decomposition or the collection of undesirable end products which are basic in nature. The B value for haddock falls from an initial value of about 7 or 8, to a minimum of 2 to 5 soon after the fish is caught, and then as bacterial decomposition occurs it rises again to a maximum of 16 or more in extreme decomposition. Since the initial drop in B value generally occurs before haddock is landed commercially, it is usually disregarded. By comparing both the A and B values, a knowledge as to the condition of the fish is obtained. Neither value alone, however, is useful in predicting the quality of the flesh.

Several hundred samples of mackerel were obtained, in varying degrees of decomposition, and the electrometric test applied. When the results were summarized the following differences were noted between the method as applied to mackerel and to haddock:

1. The A and B values for haddock correspond quite closely to the same condition of the fish throughout the year. With mackerel the table, as prepared (see table 5), is valid only for fish of a fairly high fat content; i. e., those caught between June and September. For fish caught at other times the test is not to be recommended, since values obtained often do not correspond to the condition of the fish.

2. For mackerel caught during the summer the electrometric method cannot be considered as a final test. Other types of decomposition, such as hydrogen sulfide formation or changes in the oil, sometimes occur simultaneously and are not shown by the test. In such cases, however, the results of the electrometric test together with the other tests are valuable in appraising the condition of the fish. The A value is less affected by these other types of decomposition than is the B value.

TABLE 5.—*Condition of mackerel as indicated by electrometric test*

A value	Extent of primary change	Extent of secondary change—B values			
		B=less than 2	B=2-5	B=5-8	B=over 8
30-40	None	None	None	Slight	Considerable.
25-30	Slight	do	Slight	Definite	Do.
20-25	Considerable	do	do	Considerable	Extreme.
Under 20	Extreme	do	Definite	Extreme	Do.

NOTE.—These values apply only to mackerel caught between June and September.

HYDROGEN SULFIDE TEST

Hydrogen sulfide often forms during decomposition of mackerel. Numerous tests are available for determining the amount of hydrogen sulfide in food products. It was believed that in the case of mackerel the relatively simple test of Ebers (1897) would serve as a basis for a very suitable, rapid test. In working out this test it was decided to make use of the fact that during the early stages of decomposition hydrogen sulfide may collect in the fish and give off a bad odor when cut open, even though advanced spoilage is not present. By determining the amount of hydrogen sulfide when the fish is first cut open, and then incubating the fish for a further period, two values are obtained. A positive test for hydrogen sulfide in the first step indicates only that some small amount of decomposition has occurred, and unless it is also strongly positive in the second step, the condition of the flesh is not necessarily poor.

The following method was used: Strips of filter paper 1 inch wide were dipped for 3 to 5 minutes in a 10 percent lead acetate solution and were then allowed to dry thoroughly at room temperature. Twenty-five gm. of thoroughly ground mackerel flesh were weighed to within a few tenths of a gram into a 250 ml. Erlenmeyer flask. Fifty ml. of 6N hydrochloric acid were then added and a strip of the lead acetate paper, moistened with water, was placed across the mouth of the flask and the flask loosely stoppered with a wad of cotton. The flask was placed in an incubator for exactly 10 minutes and then withdrawn. The lead acetate strip was then replaced with a fresh one, the original one being set aside. The flask was restoppered and placed once more in the incubator and after 110 minutes the lead acetate strip was removed.

A large number of samples of mackerel of known history, and representing different degrees of decomposition, were tested in this way and the strips of lead acetate paper were saved. They were then classified into 11 groups according to the intensity of the black or brown spot of lead sulfide on the paper. The 11 degrees of intensity were numbered from 0 to 10. No. 0 was perfectly white; No. 1 was slightly yellowish; No. 2 was a faint yellow ring, etc.; up to No. 10, which was a black circle.

The amount of hydrogen sulfide corresponding to each strip was next determined so that it would be possible to duplicate the set of strips at any time in preparing a set of standards. A solution of sodium sulfide was made up, standardized with iodine, and then diluted with hydrogen-sulfide-free water. Varying amounts of this standardized sodium sulfide solution were placed in Erlenmeyer flasks containing hydrochloric acid. The flasks were stoppered with cotton, a lead acetate paper placed in the neck, and the solution boiled. This was repeated with suitable amounts of the sodium-sulfide solution until 11 strips were obtained which matched the 11 groups of paper obtained from the fish tests (see table 6).

TABLE 6.—*Test papers for hydrogen sulfide determination*

Strip No.	Discoloration	Sulfide (S)
		Milligrams
0	No trace of yellow	0.000
1	Faint yellow color	[1].001
2	Yellow, concentrated in ridges	.002
3	Light yellow-brown color in indefinite rings	.004
4	Yellow-brown in fairly definite rings	.005
5	Brown in definite rings	.006
6	Brown in definite, fairly solid rings	.007
7	Brown in definite, solid rings	.008
8	Brown (with black predominating over yellow tinge) solid rings	.009
9	Dark brown, nearly black, solid rings	.010
10	Practically black solid rings; edges tapering off to brown	[2].010

[1] Or less. [2] Or more.

In making this test it is important that the fish be filleted and ground as rapidly as possible. The sample must be weighed immediately, the acid added, the strip of paper and stopper put in place, and the test started. Otherwise, the first test strip obtained after a 10-minute incubation will be meaningless, since much of the hydrogen sulfide would have escaped before the test was under way.

Two lead sulfide strips were obtained by this test. The first one resulting from 10-minute incubation will be designated A, while the second will be designated B. High values of A indicate that some decomposition has occurred, so that hydrogen sulfide has collected in the flesh. However, unless B is also high no extensive decomposition has taken place.

TESTS FOR OIL DECOMPOSITION

As stated in the discussion of the problems of mackerel spoilage, the principal types of fat, or oil decomposition are hydrolysis and oxidation. The method for measuring the degree of hydrolysis—the free fatty acid value—in which a known quantity of oil is neutralized with an alkali solution of known strength is quite generally standardized. The matter of measuring oxidation, however, is rather more complicated, since primary interest in the oxidation of the fat or oil of a food product pertains to its relation to rancidity. In most practical cases the principal concern is incipient rancidity, rather than readily detectable "off" flavors and odors. While rancid odors and flavors are generally attributed to oxidation, not all off flavors and odors are specifically the result of oxidation alone. Consequently numerous tests have been suggested in an attempt to correlate some chemical change in the fat or oil with the development of rancid odors and flavors. For the present investigation the writers selected a method which is quite commonly known as the peroxide test. It is based on the assumption that peroxides which can be readily broken down in the presence of potassium iodide with the liberation of iodine are found as an intermediate step during the oxidation of the oil.

In studying oil decomposition in a product such as mackerel it is necessary to separate the oil from the other body constituents. In the present investigation the method described by Stansby (1935) was used. It may be given briefly as follows:

The mackerel flesh, free of skin and bones, is ground thoroughly in a meat grinder. Twenty gm. of the flesh is weighed into a 150-ml. oil sample bottle, and 25 gm. of anhydrous sodium sulfate and exactly 100 ml. of ethyl ether are added. The bottle is shaken for exactly 30 minutes in a shaking machine and allowed to stand until the solids settle to the bottom. Twenty ml. of the clear ether solution of oil is pipetted through a filter into a weighed beaker, and the filter washed with two 5-ml. portions of ether. The ether is evaporated on a steam bath and the beaker and oil weighed. Meanwhile two further 20-ml. portions of the ether solution are pipetted into two Erlenmeyer flasks. To one of them is added 20-ml. of ethanol (neutral to phenolphthalein) and the solution is titrated with standard sodium hydroxide solution to a pink color, permanent for at least 15 seconds after the addition of the last drop of alkali solution.

The other 20-ml. aliquot is treated with 20 ml. of chloroform and 30 ml. of glacial acetic acid. One ml. of a saturated potassium iodide solution is added immediately from a pipette, the solution shaken for exactly 1 minute, and 100 ml. of a 0.05-percent starch solution is added. The liberated iodine is then titrated with standard sodium thiosulfate to the disappearance of the blue color. A blank determination is always run, using all the reagents and the same procedure but omitting the oil. The value found for the blank is then subtracted from the titration value found for the oil. From these data the percentage of free fatty acid (as oleic) and the peroxide number according to Wheeler (1932) are calculated. The peroxide number has a fair degree of correlation with the degree of rancidity, especially at lower temperatures of storage. This fact has been demonstrated by experiments (not included in this report) on the storage of mackerel body oil at different temperatures. For mackerel packed in ice or floated, a peroxide number of 0 to 1 corresponds to an imperceptible degree of rancidity. Peroxide numbers up to 20 indicate a slight degree of rancidity while values of 20 to 40 are definitely rancid. Peroxide numbers greater than about 40 and running up to 200 or more indicate extremely rancid fish.

STUDIES ON THE KEEPING QUALITY OF FRESH MACKEREL

This portion of the work consisted of experiments to test the feasibility of improving present commercial methods of handling fresh mackerel. Experimental runs were made on methods of packing mackerel for shipment and upon the effect of various methods of dressing the fish. Experiments also were run to determine the effect of the size of mackerel upon the rate of spoilage.

GENERAL STORAGE CONDITIONS

Fish were obtained as fresh as possible from the commercial mackerel fishery and were divided into lots and dressed and packed according to the storage method being studied. When the fish were floated care was taken to reproduce, as nearly as possible, standard commercial practice. The regular Irish barrels were employed, and the fish were floated with the same proportions of ice and water as is done commercially. Care also was taken to see that an adequate supply of ice remained in the barrels at all times.

For packing fish in ice, boxes such as are employed for packing haddock were used. The mackerel were packed with an ample supply of finely crushed ice which was replaced at suitable intervals as it melted. All containers were stored at room temperature, usually about 75° F. The temperature of the fish was maintained at about 33° F.

EFFECTS OF METHODS OF PACKING FOR SHIPMENT

A number of experiments were run to determine the relative merits of several methods of packing fish for shipment. Whole fish were used—one lot being floated, another packed in ice, and in some cases eviscerated fish were packed in ice for comparative purposes. Organoleptic tests of these fish were carefully made after varying periods of storage, and at the same time the various scientific tests also were run.

Fish floated in the regular commercial manner kept in good condition for at least 1 day (see table 7). Beginning on the second or third day, however, a pronounced hydrogen sulfide odor developed. After 4 days the mackerel were usually in very poor condition. Whole fish packed in ice remained in excellent condition for a period of at least 4 days, and even after storage of 1 week were usually quite edible. A comparison of the keeping quality of fish packed by the two methods is shown in figure 6. Fish packed in ice kept for more than twice as long as those which were floated.

The hydrogen sulfide and oil tests were the most significant of the scientific tests made. The electrometric test also was run, and in general it confirmed the organoleptic tests.

Hydrogen sulfide formed much sooner and in larger quantities in the floated fish than in those packed in ice (see table 8.) The amount of hydrogen sulfide present in the flesh when the fish were first cut open was nearly as great in the floated fish after 3 days of storage as it was in the fish packed in ice after 2 weeks. Since the presence of hydrogen sulfide in fish is one of the factors detracting from its value, the large difference found is highly significant.

TABLE 7.—*Effect of methods of storage on the keeping quality of mackerel*

[XXXXX=excellent, XXXX=very good, XXX=good, XX=fair, X=poor]

Series	Sample	Time stored	Condition as indicated by organoleptic observation														
			Whole fish—floated					Whole fish—packed in ice					Eviscerated fish—packed in ice				
			General appearance	Body cavity	Texture of flesh	Odor	Numerical rating	General appearance	Body cavity	Texture of flesh	Odor	Numerical rating	General appearance	Body cavity	Texture of flesh	Odor	Numerical rating
		Days	*X=6*	*X=3*	*X=2*	*X=9*		*X=6*	*X=3*	*X=2*	*X=9*		*X=6*	*X=3*	*X=2*	*X=9*	
Bc 173	A	0	XXXXX	XXXXX	XXXXX	XXXXX	100	XXXXX	XXXXX	XXXXX	XXXXX	100	XXXXX	XXXXX	XXXXX	XXXXX	100
	B	3	XXXX	XX	XX	XXX	61	XXXXX	XXX	XXXX	XXXX	83	XXXXX	XXX	XXXX	XXXXX	92
	C	7	X	X	X	X	20	XX	XX	XXXX	XXXX	62	XXXX	XXXXX	XXXX	XXXX	83
	D	10	X	----	----	----	6	XX	X	X	XX	35	XXX	XXXXX	XXXX	XXX	68
	E	15	----	----	X	----	2	----	X	XXX	X	18	XXX	XXXXX	XXXXX	XXXX	79
Bh 25	A	0	XXXX	XX	XXXXX	XXX	67	XXXX	XX	XXXXX	XXX	67	XXXX	XX	XXXXX	XXX	67
	B	1	XXX	XX	X	XXX	53	XXX	XX	X	XXX	53	----	----	----	----	----
	C	2	XX	XX	X	XX	38	XXX	XX	X	XXXX	62	----	----	----	----	----
	D	4	XX	XX	X	X	29	XX	XX	X	XXXX	56	XXXX	X	XX	XXXX	67
	E	9	----	----	----	----	----	----	----	----	----	----	XXXX	XX	XXXX	XXX	65

Analyses of the oil of mackerel packed by the 2 methods (see table 9) show that the free fatty acid formation is considerably retarded by packing the fish in ice, whereas little actual difference in peroxide number could be shown for the different packing methods. The floated mackerel showed a sharp rise in free fatty acid to a maximum value of 85 percent after 2 weeks, while the ice-stored fish contained less than 8 percent free fatty acid in the oil after a like period. On the other hand, no definite correlation between packing method and peroxide number could be demonstrated. The peroxide number varied considerably from one fish to another, but with no marked difference in favor of the floated or ice-stored fish.

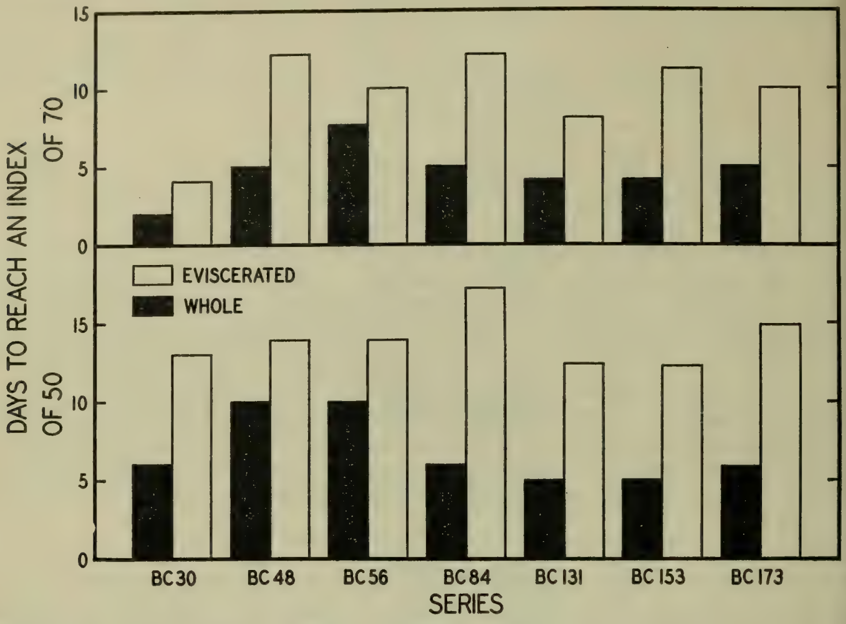


Figure 6.—Comparative keeping qualities of whole and eviscerated mackerel packed in ice, determined organoleptically. An index of 70 corresponds to a condition in which the fish, though not strictly fresh, are in fairly good condition. An index of 50 corresponds to incipient decomposition.

Table 8.—*Hydrogen sulfide formation in floated and iced mackerel, in parts per billion*

Sample	Time stored	Hydrogen sulfide content[1]			
		Floated mackerel		Iced mackerel	
		When opened	After 2 hours	When opened	After 2 hours
A	0	0	0	0	0
B	3	320	160	0	40
C	7	400	360	0	160
D	10	<400	<400	160	320
E	14	<400	<400	360	<400

[1] Expressed as sulfide sulfur in parts per billion.

One reason for the widespread custom of floating mackerel is the belief that this method reduces bleaching of the color from the surface of the fish. Observations were made as to this point during the course of the experiments. After 3 days' storage no difference in bleaching of the colors could be detected between the floated and iced fish. After storage in ice for 1 week the mackerel were definitely lighter in color than when freshly iced—the stripes being more or less faded, the background a greyish hue, and the pearlescent colors had completely disappeared. Mackerel which had been floated for 1 week did not show such a marked bleaching but were usually very stale, if not definitely decomposed.

Table 9.—*Effect of method of packing mackerel upon oil decomposition*

Sample	Time stored	Free fatty acid value		Peroxide number	
		Floated mackerel	Mackerel iced in boxes	Floated mackerel	Mackerel iced in boxes
	Days	*Percent*	*Percent*	[1]	[1]
A	0	3.4	3.4	0	0
B	3	2.6	3.3	5.8	1.2
C	7	18.2	2.5	8.0	4.2
D	10	16.8	4.6	0	10.6
E	14	85.2	7.7	15.6	23.0

[1] Millimoles of peroxide per kilograms of oil.

In order to further check the amount of leaching caused by the melting ice, a series of analyses were made for the mineral content of mackerel floated and iced for varying periods. The fish at first contained 1.35 percent ash. After 3 days' storage the iced fish showed no decrease in ash content. After storage for 1 week the iced fish were slightly lower in ash content (1.14 percent) than the floated fish (1.28 percent). It was not until 2 weeks' storage had elapsed that a really pronounced difference occurred. At this time the iced fish contained 0.92 percent ash, as compared with 1.58 percent ash for the floated fish. The increase in this latter sample can be attributed to the decomposed condition of the fish which permitted them to absorb salt from the brine in which they were floated.

Another beneficial result attributed to floating is the prevention of ice marks. Observations were made as to the development of marks on the iced samples and it was soon apparent that if suitable precautions were taken, little or no ice marking of the fish would result. If large pieces of ice were used, and the fish roughly handled, ice marks developed after a very short storage period. On the other hand, if finely crushed ice—such as is used aboard mackerel boats—was employed, and if care was taken to pack the fish in boxes, then no bruising of the fish by ice was encountered. It was believed that possibly the ice marking would be accentuated by actual shipment of the fish, since jostling during transportation might lead to more damage being done by the ice. In order to test this point, two shipments of mackerel were made from Boston, Mass., to Washington, D. C., the fish being packed in boxes of ice. When received in Washington these fish exhibited no signs whatever of ice marks.

An attempt was made to improve the floating of fish. The fish were floated in untreated sea water, sea water treated with perchloron (a germicidal substance), and in a salt-brine solution. The fish floated in the treated sea water kept slightly better than the fish floated in untreated sea water. When a prepared brine was used for floating no improvement in keeping quality of the fish was obtained. These results indicate that floating cannot be used for storing fish successfully, even if the floating water is free of bacteria.

EFFECTS OF METHODS OF DRESSING

COMPARISON OF DRESSING PROCEDURES

A preliminary series of tests was run to compare different methods of dressing. Some of the fish were filleted, some eviscerated, some gibbed, and some were left in the round. Each group was stored separately in boxes of crushed ice. The fillets were wrapped in moistureproof paper and placed in metal fillet boxes to protect them from the melting ice.

Observations made on these fish in storage (see table 10) disclosed the fact that dressed fish kept considerably better than those left in the round; being in better condition after 17 days than the round fish were after 1 week. The fillets kept for 1 week in about the same condition as the round fish and then deteriorated rapidly. The gibbed fish did not keep quite as well as those eviscerated, but very much better than those left in the round.

TABLE 10.—*Effect of methods of dressing on the keeping quality of mackerel packed in ice*

[XXXXX=excellent, XXXX=very good, XXX=good, XX=fair, X=poor]

Series	Sample	Time stored	Condition as indicated by organoleptic observation									
			Eviscerated fish					Gibbed fish				
			General appearance	Body cavity	Texture of flesh	Odor	Numerical rating	General appearance	Body cavity	Texture of flesh	Odor	Numerical rating
		Days	*X=6*	*X=3*	*X=2*	*X=9*		*X=6*	*X=3*	*X=2*	*X=9*	
Bc 153	A	0	XXXXX	XXXXX	XXXXX	XXXXX	100	XXXXX	XXXXX	XXXXX	XXXXX	100
	B	3	XXX	XXXX	XXXX	XXXXX	83	XXX	XXXX	XXXX	XXXXX	83
	C	7	XXXX	XXXXX	XXX	XXXXX	90	XXXX	XXXXX	XXX	XXXX	81
	D	11	XXXX	XX	XXXX	XXXX	74	XXX	XX	XXXX	XXX	59
	E	14	XX	XX	XXXX	XXX	53	XX	XX	XXXX	XXX	53
	F	17	XX	XXX	XXXXX	XXX	58	XXX	XX	XXXX	XX	50
Bc 173	A	0	XXXXX	XXXXX	XXXXX	XXXXX	100	XXXXX	XXXXX	XXXXX	XXXXX	100
	B	3	XXXXX	XXX	XXXX	XXXXX	92	XXXXX	XXXXX	XXXX	XXXX	89
	C	7	XXXX	XXXXX	XXXX	XXXX	83	XXXX	XXXXX	XXXX	XXXX	83
	D	10	XXX	XXXXX	XXXX	XXX	68	XXX	XXX	XXXX	XXXX	71
	E	15	XXX	XXXXX	XXXX	XXXX	77	X	X	X	XXX	38

Series	Sample	Time stored	Condition as indicated by organoleptic observation									
			Whole fish					Fillets				
			General appearance	Body cavity	Texture of flesh	Odor	Numerical rating	General appearance	Body cavity	Texture of flesh	Odor	Numerical rating
		Days	*X=6*	*X=3*	*X=2*	*X=9*		*X=6*	*X=3*	*X=2*	*X=9*	
Bc 153	A	0	XXXXX	XXXXX	XXXXX	XXXXX	100	XXXXX	XXXXX	XXXXX	XXXXX	100
	B	3	XXX	XXX	XXXX	XXXXX	80	XXX	(1)	XXXX	XXXX	73
	C	7	XXX	XXX	-----	X	36	XX	(1)	X	XX	38
	D	11	XX	X	XX	XX	37	X	(1)	X	X	20
	E	14	X	-----	XXX	XX	30	X	(1)	X	-----	9
	F	17	XXX	X	X	X	32	-----	(1)	-----	-----	0
Bc 173	A	0	XXXXX	XXXXX	XXXXX	XXXXX	100	-----	-----	-----	-----	-----
	B	3	XXXXX	XXX	XXXX	XXXX	83	-----	-----	-----	-----	-----
	C	7	XX	XX	XXXX	XXXX	62	-----	-----	-----	-----	-----
	D	10	XX	X	X	XX	35	-----	-----	-----	-----	-----
	E	15	-----	X	XXX	X	18	-----	-----	-----	-----	-----

[1] No weight given to this factor, since these were fillets, but a correction was applied to the total rating to compensate for this omission.

The foregoing experiments indicated that mackerel would keep better if eviscerated than if stored whole. However, it was believed advisable to repeat these experiments on a large number of fish at different seasons of the year, so as to take into account any differences caused by varying fat content, presence of red feed in the fish, or other factors. Accordingly, 9 lots of fish were procured at different times, ranging from early summer to late autumn. Fish in each lot were divided into two groups, one of which was left in the round and the other eviscerated. Both dressed and whole fish were then packed in ice and organoleptic and scientific tests were run at intervals. The results of these tests (see table 11) fully confirmed the results of the earlier experiments. In every series the eviscerated fish kept better than the round ones. In some cases the storage life was more than doubled by eviscerating (see figure 6). The biggest improvement was obtained in cases where considerable red feed was present in the fish and the evisceration was carried out immediately after the fish had been caught. On the other hand, evisceration had the least effect in cases where the fish contained much red feed and were not eviscerated until some time had elapsed after catching. The eviscerated fish kept from 41 to 177 percent longer than those left in the round, the average increase in storage life being 119 percent (see table 12).

TABLE 11.—*Effect of evisceration on the keeping quality of mackerel packed in ice*

[XXXXX=excellent, XXXX=very good, XXX=good, XX=fair, X=poor]

Series	Sample	Time stored	Condition as indicated by organoleptic observation									
			Eviscerated mackerel					Whole mackerel				
			General appearance	Body cavity	Texture of flesh	Odor	Numerical rating	General appearance	Body cavity	Texture of flesh	Odor	Numerical rating
		Days	*X=6*	*X=3*	*X=2*	*X=9*		*X=6*	*X=3*	*X=2*	*X=9*	
Bc 29	A	0	XXXX	XXXXX	XXXXX	XXXXX	94	XXXX	XXXXX	XXXXX	XXXXX	94
	B	7	-----	-----	-----	-----	-----	X	XX	X	XX	32
	C	11	-----	-----	-----	-----	-----	-----	X	-----	X	12
	D	14	X	XXX	X	XX	35	-----	-----	-----	X	9
Bc 30	A	0	XXXX	XXXXX	XXXXX	XXXX	85	XXXX	XXXXX	XXXXX	XXXX	85
	B	3	XXXX	XXXXX	XXXX	XXX	74	XXX	XXX	XXXX	XXX	62
	C	6	XXX	XXXXX	XXXX	XXX	68	XXX	XXX	X	XX	47
	D	10	XXX	XXXX	XX	XXX	61	XX	X	-----	XX	33
	E	13	XXX	XX	X	XXX	53	X	-----	-----	-----	6
	F	19	XXX	XXX	X	XXX	56	XXX	X	-----	X	30
	G	22	X	XXX	X	XX	35	-----	-----	-----	X	9
Bc 48	A	0	XXXXX	XXXXX	XXXXX	XXXXX	100	XXXXX	XXXXX	XXXXX	XXXXX	100
	B	1	XXXXX	XXXXX	XXX	XX	69	XXXXX	XXXX	XXX	XXX	75
	C	4	XXX	XXXX	XXXXX	XXXXX	85	XXX	XX	XXX	XXXXX	75
	D	6	XXXX	XXXXX	XXXXX	XXXXX	94	XX	X	XXXX	XXXX	59
	E	8	XXX	XXXXX	XXX	XXXX	75	XX	XX	XX	XXX	49
	F	11	XXX	XXXX	XXXXX	XXXX	76	XX	X	XXX	XXX	48
	G	14	X	XXX	XX	XXX	46	X	-----	XX	X	19
	H	16	XX	XX	XX	XX	40	X	-----	X	X	17
Bc 56	A	0	XXXXX	XXXXX	XXXXX	XXXXX	100	XXXXX	XXXXX	XXXXX	XXXXX	100
	B	2	XXXX	XXXXX	XXXXX	XXXXX	94	XXXXX	XXXX	XXX	XXX	75
	C	6	XXXX	XXXXX	XXXX	XXXXX	92	XX	XXXX	XX	XXXXX	76
	D	14	X	XX	XXX	XXX	45	-----	X	XX	XX	25
	E	18	-----	XXX	X	X	20	-----	X	X	-----	5
	F	21	-----	XX	X	-----	8	-----	-----	-----	-----	0
Bc 68	A	0	XXXXX	XXXXX	XXXXX	XXXXX	100	XXXXX	XXXXX	XXXXX	XXXXX	100
	B	4	XXXX	XXXXX	XXXX	XXXXX	92	XX	XX	XX	XXXX	58
	C	7	XXXX	XXXX	XXXX	XXXX	80	XX	XXXX	XXXX	XXXXX	77
	D	10	XX	XXX	XX	XX	43	X	-----	-----	XXX	33

TABLE 11.—*Effect of evisceration on the keeping quality of mackerel packed in ice*—Continued

[XXXXX=excellent, XXXX=very good, XXX=good, XX=fair, X=poor]

Series	Sample	Time stored	Condition as indicated by organoleptic observation									
			Eviscerated mackerel					Whole mackerel				
			General appearance	Body cavity	Texture of flesh	Odor	Numerical rating	General appearance	Body cavity	Texture of flesh	Odor	Numerical rating
		Days	*X=6*	*X=3*	*X=2*	*X=9*		*X=6*	*X=3*	*X=2*	*X=9*	
Bc 84	A	0	XXXXX	XXXXX	XXXXX	XXXXX	100	XXXXX	XXXXX	XXXXX	XXXXX	100
	B	4	XXXXX	XXXXX	XXXXX	XXXXX	100	XXXXX	XXXX	XXXX	XXXXX	95
	C	7	XXXX	XXXXX	XXXX	XXXX	83	XX	X	XX	XX	37
	D	12	XXX	XXXX	XXXXX	XXX	67	XX	X	XX	X	28
	E	18	XXX	XXXXX	XXXX	XXX	68	XX	XX	XX	XX	40
Bc 131	A	0	XXXXX	XXXXX	XXXXX	XXXXX	100	XXXXX	XXXXX	XXXXX	XXXXX	100
	B	8	X	XXX	XXXX	XXXX	59	X	-----	-----	X	15
	C	11	XX	XXX	XXXX	XXXX	65	-----	-----	-----	XX	18
	D	17	XX	XXX	XXXX	X	38	-----	-----	-----	X	9
	E	23	X	XX	X	X	23	-----	-----	-----	X	9
Bc 141	A	0	XXX	XXX	XXX	XXXXX	78	XXX	XXX	XXX	XXXXX	78
	B	8	XX	XX	XXX	XXXX	60	X	X	X	XX	29
	C	17	XX	X	XX	XX	37	-----	-----	-----	X	9
	D	17	XX	X	XX	XX	37	-----	-----	-----	X	9
Bc 145	A	0	XXX	XXX	XXXX	XXXX	71	XXX	XXX	XXXX	XXXX	71
	B	6	XXX	XX	XXXX	XXXX	68	X	-----	-----	XX	24
	C	15	XX	X	X	XX	35	-----	-----	-----	-----	0
	D	15	XX	X	X	XX	35	-----	-----	-----	-----	0

TABLE 12.—*Increase in storage life of eviscerated mackerel, as compared with whole mackerel, packed in ice*

Series	Increase in storage life due to evisceration			Series	Increase in storage life due to evisceration		
	To reach a freshness index of 70 [1]	To reach a freshness index of 50 [2]	Average		To reach a freshness index of 70 [1]	To reach a freshness index of 50 [2]	Average
	Percent	*Percent*	*Percent*		*Percent*	*Percent*	*Percent*
Bc 30	100	117	108	Bc 131	100	140	120
Bc 48	140	40	90	Bc 153	175	180	177
Bc 56	43	40	41	Bc 173	100	150	125
Bc 84	140	200	170	Average	114	124	119

[1] Fish in good condition although not strictly fresh.
[2] Incipient decomposition; fish barely edible.

The electrometric test was run on all series. As mentioned previously, results by this test are useful only when obtained on fairly oily fish. The electrometric tests confirmed the organoleptic results, showing that eviscerated fish keep much better than the whole ones. Results of one such series are given in table 13. In this series it required about 13 days for the eviscerated fish to reach an index value of 20 (still fairly good, though not fresh), a value reached by the whole fish in 6 days. When applied to mackerel caught in the fall, the test gave erratic results.

TABLE 13.—*Keeping quality of whole and eviscerated mackerel packed in ice, as indicated by the electrometric test*

Sample	Time stored	Freshness					
		Whole mackerel			Eviscerated mackerel		
		A value	B value	B−A+40	A value	B value	B−A+40
	Days						
A	0	35.5	3.0	7.5	35.5	3.0	7.5
B	3	32.2	4.8	12.6	34.9	3.1	8.2
C	6	21.7	1.8	20.1	27.3	4.3	17.0
D	10	22.0	3.5	21.5	25.0	1.7	16.7
E	13	20.4	5.5	25.1	19.8	2.1	22.3
F	19	19.6	4.4	24.8	22.0	3.6	21.6
G	22	19.9	9.4	29.5	18.6	5.4	26.8

BACTERIAL GROWTH [2]

Bacterial counts were made on the fish in five of the test series and in general the eviscerated fish showed higher bacterial counts than the whole fish (see table 14.) This indicates that evisceration stops autolytic rather than bacterial decomposition.

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[2] The bacterial counts reported in this section were made by Francis P. Griffiths, formerly junior bacteriologist, U. S. Bureau of Fisheries.

TABLE 14.—*Bacterial count of whole and eviscerated mackerel packed in ice*

Series	Sample	Time stored	Bacterial count per gram of flesh			
			Whole mackerel		Eviscerated mackerel	
		Days	*Number*	*Logarithm of number*	*Number*	*Logarithm of number*
Bc 30	A	0	2,900	3.5	2,900	3.5
	B	3	9,000	4.0	2,000	3.3
	C	10	360,000	5.6	800,000	5.9
	D	13	1,600,000	6.2	23,000,000	7.4
Bc 48	A	0	50,000	4.7	50,000	4.7
	B	4	100,000	5.0	160,000	5.2
	C	6	160,000	5.2	6,000,000	6.8
	D	8	900,000	6.0	3,500,000	6.5
	E	11	4,900,000	6.7	12,500,000	7.1
	F	14	8,500,000	6.9	16,000,000	7.2
	G	16	10,000,000	7.0	2,000,000,000	9.3
Bc 56	A	0	16,000	4.2	16,000	4.2
	B	2	150,000	5.2	7,000	3.8
	C	6	180,000	5.3	530,000	5.7
	D	14	4,500,000	6.7	4,400,000	6.6
	E	18	46,000,000	7.7	150,000,000	8.2
	F	21	90,000,000	8.0	130,000,000	8.1
Bc 68	A	0	15,000	4.2	15,000	4.2
	B	4	15,000	4.2	44,000	4.6
	C	7	330,000	5.5	400,000	5.6
Bc 84	A	0	3,800	3.6	3,800	3.6
	B	4	80,000	4.9	200,000	5.3
	C	7	1,400,000	6.1	4,000,000	6.6
	D	12	14,000,000	7.1	14,000,000	7.1
	D	12	41,000,000	7.6	84,000,000	7.9
	E	18	325,000,000	8.5	180,000,000	8.3
	E	18	116,000,000	8.1	120,000,000	8.1

Since the bacterial counts showed that the eviscerated fish were somewhat more contaminated with bacteria than the whole ones, some experiments were made to see if a treatment of the eviscerated fish with a germicide might reduce such contamination and increase the storage life of the fish. Two types of chemicals were tried, one a hypochlorite (perchloron) and the other an organic compound (chloramine T). Both of these chemicals give off chlorine when dissolved in water. The former was found to be less effective than the latter, since it decomposed very rapidly when in contact with the fish. It was also found that there was an upper limit to the concentration of such compounds which could be used on fish. This maximum limit was a solution containing about 10 parts per million of available chlorine. If stronger solutions were used, the fish were bleached in color and a pronounced chlorine odor was retained by the fish. After being eviscerated the fish were dipped in a solution containing 10 parts per million of available chlorine for 1 minute. While such a treatment definitely reduced the bacterial contamination, it did not increase the storage life of the fish. On the contrary, in some instances the spoilage rate was somewhat increased (see table 15). These results are in agreement with those reported by Stansby and Griffiths (1935) on the chemical treatment of haddock fillets. Apparently even a solution of 10 parts per million of available chlorine reacts with the fish protein, altering it to a form which is more readily attacked by bacteria. Bacterial counts on mackerel treated with such antiseptic solutions showed a decrease immediately after treatment, but upon subsequent storage in ice the counts on the treated fish increased more rapidly than in the case of the untreated mackerel.

TABLE 15.—*Effect of chemical treatment on the keeping quality of eviscerated mackerel packed in ice*

[XXXXX=excellent, XXXX=very good, XXX=good, XX=fair, X=poor]

Sample	Time stored	Condition as indicated by organoleptic examination									
		Untreated fish					Treated fish[1]				
		General appearance	Body cavity	Texture of flesh	Odor	Numerical rating	General appearance	Body cavity	Texture of flesh	Odor	Numerical rating
	Days	*X=6*	*X=3*	*X=2*	*X=9*		*X=6*	*X=3*	*X=2*	*X=9*	
A	0	XXXXX	XXXXX	XXXXX	XXXXX	100	XXXXX	XXXXX	XXXXX	XXXXX	100
B	8	X	XXX	XXXX	XXXX	59	XX	XXX	XXX	XX	45
C	11	XX	XXX	XXXX	XXXX	65	XX	XX	X	X	38
D	17	XX	XXX	XXXX	X	38	X	XX	X	XX	32
E	23	X	XX	X	X	23	X	XX	X	X	23

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[1] Fish dipped for 1 minute in a solution of chloramine T containing 10 parts per million of available chlorine.

OIL DECOMPOSITION

Tests on the oil in the eviscerated and whole fish (see table 16) indicate a somewhat greater rate of oxidation of the oil and a slightly lower rate of free fatty acid formation in the eviscerated fish. Especially during the first few days of storage, the eviscerated fish have higher peroxide numbers in the oil than the whole fish and the difference is sometimes quite pronounced. For the first few days of storage the whole fish show peroxide numbers of 0 to 1, with the average about 0.6. The corresponding peroxide numbers for eviscerated fish range from 0 to 8, with an average of about 4. Peroxide numbers of 0 to 1 usually correspond to a degree of rancidity so small as to be imperceptible, while values up to 8 usually correspond to a slight degree of rancidity.

In order to further check the difference in rancidity between the eviscerated and whole mackerel, cooking and tasting tests were made. It was found that the average person could not distinguish between the oil from eviscerated and whole mackerel. However, persons with unusually acute sense of taste pronounced the eviscerated fish to have a slight degree of rancid flavor as compared to no rancidity in the whole fish. In fish stored for more than 3 days no difference could be detected by tasting tests, since both the whole and eviscerated fish possess a slight degree of rancidity.

TABLE 16.—*Keeping quality of the oil in whole and eviscerated mackerel packed in ice*

Time stored	Peroxide number [1]						Free fatty acid value [2]					
	Whole mackerel			Eviscerated mackerel			Whole mackerel			Eviscerated mackerel		
	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
Days	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
0	0.6	0	0.1	0.6	0	0.1	3.4	1.5	2.4	3.4	1.4	2.4
1–3	1.2	0	.6	8.2	0	4.1	3.8	3.3	3.6	4.7	1.7	3.2
4–7	4.9	.6	3.2	15.0	.4	6.9	7.9	2.5	4.5	3.4	2.2	2.9
8–11	10.6	2.6	6.4	10.1	1.6	5.9	5.1	2.1	3.9	5.0	1.8	2.9
Over 11	23.0	3.4	7.9	38.5	6.2	11.8	7.8	2.4	4.9	7.9	2.6	4.1

[1] Millimoles peroxide per kilogram of oil.
[2] Percent of free fatty acid.

SHRINKAGE OF EVISCERATED FISH

If fish are eviscerated there will be a reduction in weight due to the loss of the viscera. A number of experiments were run to determine the percent of loss from this source (see table 17). The loss in weight averages 8 percent, with a fairly small deviation from this value from fish to fish. During season the roe could be saved for sale as a byproduct, since it is eaten by many people, and if this was done it should more than offset the cost of evisceration and the accompanying shrinkage.

When fish are packed in ice they either gain or lose weight, depending upon storage conditions. A few experiments were run to determine the nature and extent of such changes in eviscerated and whole mackerel. Preliminary work showed that unless the fish were kept well covered with ice rather large losses in weight occurred, due to evaporation. When sufficient ice was present to cover the fish at all times, the loss from this source was kept at a minimum. Although whole fish usually lost less weight than the eviscerated fish when stored in ice (see table 18), the loss in weight in either case was so small as to be almost negligible. Thus, after 8 days' storage, the loss was 3.3 percent for the eviscerated fish and 1.6 percent for the whole fish. Moreover, after prolonged storage the eviscerated fish lost slightly less weight (6.8 percent) than the whole fish (7.9 percent). The importance of keeping the fish well covered with ice cannot be overemphasized. When an inadequate amount of ice is present, losses in weight are often several times as high as the figures given above.

Table 17.—*Loss in weight of mackerel due to evisceration* [1]

Weight of whole fish	Weight of eviscerated fish	Loss in weight	Weight of whole fish	Weight of eviscerated fish	Loss in weight
		Percent			*Percent*
363	338	6.9	461	421	8.6
412	381	7.5	498	450	9.6
416	386	7.2	533	494	7.3
421	386	8.3			
449	414	7.8	Average		8.0
459	420	8.5			

[1] Weight is given in grams.

Table 18.—*Changes in weight of whole and eviscerated mackerel stored in ice*

Sample	Time stored	Changes in weight		Sample	Time stored	Changes in weight	
		Whole fish	Eviscerated fish			Whole fish	Eviscerated fish
	Days	*Percent*	*Percent*		*Days*	*Percent*	*Percent*
A	2	+1.1	+1.1	A	11	0	−5.2
B	2	0	−2.3	B	11	−6.4	−4.5
C	2	−0.7	−1.7	C	11	−1.5	−5.1
D	2		−.9	D	11		−1.2
Average	2	+0.1	−.9	Average	11	−2.6	−4.0
A	8	+1.5	−3.9	A	17	−9.0	−6.5
B	8	−5.4	−4.2	B	17	−6.9	−8.4
C	8	−0.6	−4.1	C	17		−4.8
D	8		.6	Average	17	−7.9	−4.9
Average	8	−1.6	−3.3				

INFLUENCE OF DELAY IN DRESSING

Experiments were conducted to determine whether it is necessary to dress mackerel immediately after they are caught in order to increase their keeping quality. About 100 mackerel were obtained which had been caught 12 hours previously. These were divided into several lots; one lot being eviscerated, another gibbed, and a third left in the round—all three being packed in ice. A fourth lot was floated in the ordinary commercial manner. After 1, 2, and 4 days of storage some of the iced whole fish and some of the floated fish were withdrawn and subdivided into two lots, one of which was gibbed and the other eviscerated. They were labeled to distinguish the different treatments, again packed in ice, and, after a total of 9 days of storage, careful organoleptic tests were made on all samples.

The results of these experiments indicate that mackerel should be dressed as soon as possible after catching in order to insure maximum keeping quality (see table 19). Fish held up to 36 hours in ice (including 12 hours aboard the fishing boat) and then dressed, showed no appreciable decrease in keeping quality over those dressed at the earliest possible time. Fish floated for 1 day, or stored in ice for 2 days, were not greatly benefitted by being dressed, although they did keep slightly better than those stored whole for the entire period. These experiments indicate that fish should be dressed either aboard the fishing boat or immediately after they are landed. If they are shipped in the round and eviscerated when received by the retailer, much of the advantage of evisceration will be lost.

TABLE 19.—*Effect of time and method of handling, prior to dressing, on subsequent keeping quality of mackerel*

[XXXXX=excellent, XXXX=very good, XXX=good, XX=fair, X=poor]

Method and time of storage (days)	Condition of dressed fish after a total of 9 days in storage									
	Eviscerated and packed in ice					Gibbed and packed in ice				
	General appearance	Body cavity	Texture of flesh	Odor	Numerical rating	General appearance	Body cavity	Texture of flesh	Odor	Numerical rating
Whole fish, floated:	*X=6*	*X=3*	*X=2*	*X=9*		*X=6*	*X=3*	*X=2*	*X=9*	
0	XXXX	XX	XXXX	XXX	65	XXXX	X	XXXX	XX	53
1	XX	X	XX	XX	37	XX	X	X	XX	35
2	XX	-------	X	X	23	XX	-------	-------	X	21
4	X	X	-------	-------	9	X	-------	-------	-------	6
9	-------	-------	-------	-------	0	-------	-------	-------	-------	0
Whole fish, iced:										
0	XXXX	XX	XXXX	XXX	65	XXXX	X	XXXX	XX	53
1	XXXX	X	XXX	XXX	60	XXXX	X	XXX	XX	51
2	XXX	X	XX	XX	43	XXX	X	XX	XX	43
4	XX	X	X	X	26	XX	X	X	X	26
9	XX	-------	-------	X	21	XX	-------	-------	X	21

EFFECT OF SIZE OF FISH UPON SPOILAGE RATE

One series of fish was used to determine the effect of the size of the fish upon the spoilage rate. The fish for this test were obtained directly from a fishing boat, and had been caught about 6 to 10 hours previously. These fish were divided into two lots, one lot having an average weight of 0.77 pound and the other an average weight of 1.6 pounds. They were then floated whole in mackerel barrels containing harbor water.

The difference in spoilage rate was quite evident. After 6 days in storage the small fish were badly decomposed, with viscera protruding through the skin, while the large fish were in better condition. Table 20 summarizes the organoleptic tests. One difference in spoilage which was quite marked was the effect of the size of the fish upon the degree of rigor mortis. The small fish never reached the same pronounced degree of stiffness that the large ones did, and the stiffness wore off more rapidly. After 2 days rigor mortis declined in both lots. After 4 days the small fish were only slightly stiff in the tail region, whereas the large fish were fairly stiff throughout. This relative difference persisted to the end of the series. In this connection it is interesting to note the A value of the electrometric test, which is more or less proportional to the degree of rigor present. In this instance it was consistently higher for the larger fish (see table 21).

TABLE 20.—*Effect of size upon the keeping quality of floated mackerel*

[XXXXX=excellent, XXXX=very good, XXX=good, XX=fair, X=poor]

Sample	Time stored	Condition as indicated by organoleptic examination									
		Small fish					Large fish				
		General appearance	Body cavity	Texture of flesh	Odor	Numerical rating	General appearance	Body cavity	Texture of flesh	Odor	Numerical rating
	Days	*X=6*	*X=3*	*X=2*	*X=9*		*X=6*	*X=3*	*X=2*	*X=9*	
A	0	XXXX	XXXXX	XXXXX	XXXXX	94	XXXXX	XXXXX	X	XXXX	83
B	2	XXX	XXXX	XXXX	XXX	65	XXX	XXXXX	XXXX	XXXX	77
C	4	XX	XXX	X	XX	41	XXX	XXXXX	X	XXXX	71
D	6	X	XX	--------	XX	30	XX	XXX	X	XX	41
E	8	X	X	X	X	20	XXX	X	X	--------	23

TABLE 21.—*Effect of size of fish on rigor mortis*

Storage time	Small fish		Large fish	
	Degree of rigor mortis	A value	Degree of rigor mortis	A value
Days				
0	Fairly stiff	26.2	Very stiff	29.0
2	Rigor beginning to disappear	27.7	Very rigid	31.8
4	Fish still stiff at tail	25.5	Rigor still present though not pronounced	30.5
6	Rigor absent	22.9	Rigor present but beginning to disappear in some fish.	26.0
8	do	20.6	Rigor absent except a slight stiffness in tail region.	24.5

DISCUSSION

GENERAL CONSIDERATIONS

The foregoing section has shown that when mackerel are iced, rather than floated, a considerable increase in storage life takes place, and that the keeping quality can be further increased by eviscerating the fish as soon as possible after they are caught. It has also been shown that when reasonable care is taken in packing the fish in ice they are not unduly bruised or bleached. Indeed, it is hard to reconcile the prevailing belief that shipment of mackerel with ice alone ruins them by causing ice marks and bleaching, especially in view of the fact that mackerel are at present packed in ice on board the fishing vessels for periods up to 3 days and subjected to considerable jostling caused by the motion of the vessel. This treatment is much more drastic than the action of the ice during shipment by express which, under present methods of distribution, rarely requires over 24 hours and is accompanied by much less vibration and jostling than occurs aboard a boat. It is difficult to imagine how the ice storage on board a boat can cause no ill effects, and the subsequent shorter storage during shipment can cause so much damage; as is believed by some to be the case. Moreover, mackerel are shipped in other countries in ice without any complaint of bruising or bleaching, and some dealers in this country now ship in ice with complete satisfaction.

The advantage of icing mackerel, either in the round or eviscerated, is estimated in table 22 for fish shipped from Boston to various sections of the country. In zone 1, which includes Boston and Gloucester and the immediate vicinity the fish have usually been floated for only a few hours when received by the retailer. These fish are in excellent condition when received and if dispensed from the original container (floating) they will remain in edible condition for about 4 days. However, if these fish were held in ice by the retailer the storage life would be increased to 7 days; or to 14 days if eviscerated and iced.

TABLE 22.—*Estimated condition in which mackerel are received when shipped from Boston and vicinity under different methods of handling*

Destination (zone)	Days in transit	Method of handling					
		Floated in barrels		Iced in the round		Eviscerated and iced	
		Rating	Keeping quality	Rating	Keeping quality	Rating	Keeping quality
			Days		*Days*		*Days*
Boston, New York, and immediate vicinity, zone 1	(1)	100–90	4	100–95	7	100–95	14
Atlantic seaboard north of Philadelphia and inland to upper New York State, zone 2	1	90–85	3	95–90	6	100–90	13
Within zone 3	2	85–70	2	95–85	5	95–90	12
Within zone 4	3	70–45	1	90–85	4	90–85	11

(1) Less than 1 day.

NOTE.—Ratings are described as follows: 100–90 is excellent, 90–85 is good, 85–70 is fair, and 70–45 is poor.

Zone 2 includes the North Atlantic seaboard and inland to upper New York State. Mackerel have usually been floated for about 1 day when they are received by the retailers in this territory. These fish are in good condition when received and can be kept in the original containers (barrels) for an additional 3 days. However, if these fish were held in ice the storage life would be increased to 6 days; or to 13 days if they were eviscerated and iced.

Zone 3 comprises that territory outside of zone 2 but within a radius of approximately 1,000 miles from Boston. Mackerel are received in this zone in only fair condition, having been in transit 2 days, with an expected storage life of 2 days. If the fish were iced instead of floated they would be in excellent to good condition when received, with an expected storage life of 5 days; or 13 days if eviscerated and iced. Very little fresh mackerel is consumed in this zone, but a marked increase could be expected with improved handling methods.

Zone 4 comprises that territory outside of zone 3 but within a radius of approximately 1,500 miles from Boston. Mackerel are in poor condition when received in this area and usually can be kept for only 1 day before they become inedible. If these fish were shipped in ice they would be received in good condition, with a subsequent storage life of 4 days if kept in the round; or 11 days if eviscerated and iced. Fresh mackerel are not consumed in this territory in appreciable quantities. However, because of the universal popularity of this fish in the areas where it is obtainable in excellent to good condition, it is believed that with a general improvement in the handling of fresh mackerel the market for these fish could be substantially improved.

SHIPPING CHARGES

Not only will the abandonment of floating of mackerel increase their keeping quality but a very definite saving in transportation charges will be effected. When fish are shipped in ice the express rate is based upon the net weight of the fish plus 25 percent. Floated fish, on the other hand, are charged according to second-class rates on iced foodstuffs, which amounts to the gross weight minus 25 percent. One hundred and fifty pounds of mackerel are ordinarily shipped in an Irish barrel, the gross weight of which, including fish, ice, water, and barrel is 300 pounds. Thus, shipping charges on 150 pounds of floated mackerel are based on a weight of 225 pounds, while the same weight of mackerel, if iced, would have shipping charges based on only 188 pounds.

Table 23 gives the approximate costs of shipping 150 pounds of mackerel, floated in barrels and iced in boxes, from Boston to various cities. The average saving per box is 65 cents, or 4.4 cents per pound, and in itself is sufficient reason for discontinuing the present practice of floating mackerel.

TABLE 23.—*Approximate savings which may be effected by shipping mackerel from Boston iced in boxes rather than floated in barrels*

[Shipping costs shown are express charges in effect during this investigation]

Destination	Cost per container (net weight 150 pounds)		Saving effected by icing	
	Barrel (floated)	Box (iced)	Per box	Per pound of fish
Buffalo, N. Y.	$3.00	$2.50	$0.50	$0.033
New York, N. Y.	2.09	1.75	.34	.023
Syracuse, N. Y.	2.55	2.12	.43	.029
Chicago, Ill.	6.06	5.06	1.00	.067
Cleveland, Ohio	4.06	3.36	.70	.047
Columbus, Ohio	4.56	3.88	.68	.045
Toledo, Ohio	4.73	3.95	.78	.052
Detroit, Mich.	5.27	4.40	.87	.058
Indianapolis, Ind.	4.84	4.05	.79	.053
Philadelphia, Pa.	2.55	2.12	.43	.029

SUMMARY

1. The oil content of mackerel varies from a minimum of about 2 percent in the spring to a maximum of 20 percent or more in late summer. It also varies with other factors, notably the size of the fish. The variation in oil content is of importance in determining the food value of mackerel, the fat fish in the summer having more than twice the calorific food value of those caught in the spring.

2. The spoilage of mackerel is more complicated than that of many other species. In addition to the ordinary types of fish spoilage, the high oil content makes rancidity a problem of considerable importance.

3. Mackerel often feed upon "red feed" *Calanus finmarchicus* which, if present to any great extent in the digestive tract when the fish are caught, greatly accelerates the subsequent rate of spoilage.

4. General observations as to the appearance, texture, odor, and flavor of mackerel are the most reliable indications as to the degree of freshness.

5. Scientific tests can be used to supplement organoleptic tests in evaluating the condition of mackerel. Tests for hydrogen sulfide, and rancidity tests are of special value when used in conjunction with observations as to appearance, odor, and flavor.

6. Mackerel will keep in much better condition if packed in finely crushed ice than if floated in sea water, as is now practiced by the industry. Mackerel stored by the floating method keep in good condition for only about 4 days. When stored in boxes of ice the storage life is increased to a week or more.

7. If care is used in packing mackerel in the special grade of finely crushed ice now available for use by the mackerel boats, bruising of the fish while in transit is practically eliminated and the colors are not bleached materially, except after prolonged storage.

8. A substantial saving on express rates can be made by shipping mackerel in ice.

9. Eviscerated mackerel will keep about twice as long as whole ones, provided the fish are dressed as soon as possible after they are caught.

10. The mackerel industry is confronted with the problem of a widely fluctuating supply of fish and a very limited market. At times when mackerel are found in great abundance the price often falls to levels below production costs. By widening the market, these large fluctuations in price could be considerably diminished, greatly stabilizing the industry. It has been shown that by adopting improved methods of shipment these fish can be transported to Midwestern markets in much better condition than under methods now prevailing, thus increasing the popularity of mackerel and creating an outlet for the surplus which cannot readily be absorbed by the present limited market along the Atlantic seaboard.

RECOMMENDATIONS

I. To producers.—

1. It is recommended that the practice of floating mackerel be discontinued, and that the fish be shipped in boxes of finely crushed ice.

2. If for any reason mackerel must be floated, use sea water that has been chlorinated. Under these circumstances a label should be affixed to each barrel, similar to the one suggested below:

> **WARNING!**
>
> **REMOVE THE FISH FROM THIS BARREL IMMEDIATELY UPON RECEIPT AND PACK THEM IN ICE.**
>
> ---
>
> This barrel is intended only as a shipping container. Its use for storage purposes will result in rapid deterioration of the fish herein contained.

This practice would add but very little to the cost of production, and would materially assist in the general improvement of present retail handling methods.

3. In no case should mackerel be shipped more than 400 miles by the floating method. For distances of 400 to 1,000 miles icing in the round will usually be sufficient. However, for distances of more than 1,000 miles mackerel must be eviscerated and iced.

II. To retail fish dealers.—

1. In dealing with the wholesaler emphasize a preference for mackerel which have been shipped in ice, similar to the manner in which other species are handled.
2. When mackerel are received in barrels (floated) they should be removed from the water immediately and be repacked in crushed ice.
3. Mackerel which are eviscerated will keep much better than if left in the round. Therefore, it is to your advantage to eviscerate (dress) the mackerel you receive before placing them on sale, thus reducing losses due to spoilage. In adopting this method, you will also provide your customers with mackerel in the best possible condition—a service which should materially increase the demand for fresh mackerel.
4. If the customer indicates that the fish is to be broiled, the method of dressing illustrated in figure 3 (see p. 7) should be followed.

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USE OF LIME IN CONTROLLING STARFISH

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Research Report No. 2

USE OF LIME IN CONTROLLING STARFISH

By

VICTOR L. LOOSANOFF AND JAMES B. ENGLE

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ABSTRACT

THE STARFISH (*Asterias forbesi* Desor) is one of the most destructive enemies of shellfish on the Atlantic coast of North America, the extent of its damage to the oyster industry of Long Island Sound alone being estimated at $500,000 a year. Efforts to eradicate this pest, though made for at least a century, have been largely unavailing.

The method here presented of combating starfish suggests the use of quicklime, the destructive effect of which is produced by direct contact. Particles of the chemical spread over oyster beds quickly sink to the bottom, and, falling on the starfish, are imbedded in the delicate skin. The caustic action of slaking lime disintegrates the membrane, and the lesions rapidly increase in size. After several days the wounds penetrate the body wall and expose the internal organs. Death usually follows in a short time.

Once spread over the oyster beds, the lime retains its effectiveness for some time. Starfish not hit directly by the descending particles will eventually come in contact with them when crawling along the bottom. In the course of time their lower surfaces will become affected and disintegration will begin. The cheapness of lime, the simplicity of its application, and its comparative harmlessness to oysters and many other commercial species all indicate that it is a practical weapon for use against the inroads of starfish on oyster beds.

USE OF LIME IN CONTROLLING STARFISH

By VICTOR L. LOOSANOFF, *Director, Fishery Biological Laboratory, Milford, Conn.*, and JAMES B. ENGLE, *Oyster Culturist, Fish and Wildlife Service*

CONTENTS

	Page
Introduction	1
Methods	3
Action of lime on starfish	4
Healing of wounds	4
Eradication experiments	5
Laboratory studies	5
Field experiments	12
Effect of lime on animals other than starfish	16
Survival and growth of oysters	17
Shell movement and feeding of oysters	20
Effect of lime on animals other than starfish—Continued.	
Gonad development and spawning	23
Setting of oysters on lime-covered bottoms	23
Mollusks other than oysters	24
Eggs and fry of flatfish	26
Lobster larvae	27
Observations on other forms	27
Conclusions and recommendations	28
Literature cited	29

INTRODUCTION

The common starfish (*Asterias forbesi*) has long been regarded as one of the most destructive enemies of shellfishes on the Atlantic coast of North America. The greatest part of the loss caused by this pest is borne by the oystermen, who often find their stock depleted or entirely destroyed. Beds populated with seed oysters are especially vulnerable. Regardless of constant efforts in combating them, starfish continue to be very numerous, destroying annually several hundred thousand bushels of oysters in Long Island Sound alone. The extent of the damage caused to the oyster industry of Long Island Sound by starfish is estimated to be approximately $500,000 a year. In addition to the direct loss caused by the destruction of seed and marketable oysters, the industry spends large sums for operating starfish boats, handpicking starfish on dredge boats, and eliminating them by other methods. It is estimated that the oystermen of Connecticut expend $100,000 to $150,000 a year for this purpose.

The scallop, another valuable mollusk of the Atlantic coast, also suffers greatly from attacks by starfish. In spite of its swimming habits, the scallop often becomes a prey of the sluggish starfish. In 1931 the population of the natural scallop grounds of Buzzards Bay was seriously depleted through starfish depredations. The Massachusetts Division of Fisheries and Game reported that the value of the scallop industry in Buzzards Bay decreased from $795,000 in

1929 to $142,000 in 1931. State authorities attributed the greater part of this decrease to the gradual increase in the starfish population (Galtsoff and Loosanoff 1939).

The voracity of starfish can easily be observed under laboratory conditions if the animals are kept in a favorable environment. Experiments conducted at Milford Laboratory have shown that a medium-sized starfish may destroy as many as 5 one-year-old oysters in 1 day. In one experiment 2 starfish destroyed 25 one-year-old oysters in 3½ days, and in another a small starfish, 1.7 cm. in diameter, destroyed 25 oyster spat in 3 days. These examples indicate the extent of damage that may be caused to beds of young oysters by invading hordes of starfish.

Studies of the conditions existing on the oyster beds of Long Island Sound in the summer and fall of 1937 provided certain quantitative data, which showed that under natural conditions the heavy mortality and quick disappearance of the oyster set were due largely to starfish activities. Simultaneously with the studies of setting of oysters (Loosanoff and Engle 1940), observations were conducted on the setting of starfish. Comparison of the density of oyster and starfish sets in 8 different areas of Long Island Sound showed that the total number of starfish set was only about one-fourth less numerous than that of oysters. The distribution of starfish set according to depth corresponded closely to the oyster set. The areas that produced large numbers of young oysters produced almost equally large numbers of their enemies. At some stations, however, young starfish were found to be much more abundant than oysters. Observations on the setting of starfish indicate that it begins about 2 weeks prior to the setting of oysters. Thus, by the time the first oysters set a great many starfish are already crawling on the bottom in search of food.

Under natural conditions several species of mollusks and other small animals are available as food for starfish, and, therefore, oysters do not constitute their only diet. Nevertheless, estimating very conservatively that 1 young starfish destroys but 1 oyster spat in 1 week's time, it is possible that the majority of oyster set can be eaten by starfish within the first few days of their existence.

Efforts to eradicate starfish have been made for at least a century, but these attempts have been mostly unavailing. The method so far used consists of gathering the starfish from the bottom by use of dredges or special starfish mops and destroying the captured animals by immersion in hot water. This method, however, is slow and the unabated depredations of starfish on the oyster beds attest its inefficiency (Loosanoff 1936).

Since mechanical control of starfish on oyster beds is not very effective, the possibility of employing some toxic substance for their eradication suggested itself. Although the body of the starfish is enclosed in a skeleton of articulating calcareous plates set with rows of blunt spines, or ossicles, and appears to be rigid and well protected, its surface is covered with a delicate membrane. Between the ossicles protrude the thin contractile branchiae which, when fully extended, provide for a gaseous exchange between the sea water and body fluids. The delicate membrane covering the branchiae can easily be affected by various chemicals. These anatomical features make the starfish much more vulnerable than the oyster and some other shellfishes, which, by keeping their shells closed, protect their bodies from the injurious effects of poisons.

Experiments leading to the development of a method for chemical control of starfish have been conducted for several years (Galtsoff and Loosanoff 1939). In early experiments substances such as copper sulfate were used. Although this chemical proved lethal to starfish, several disadvantages attended its use. Large quantities were needed to create a lethal concentration; a procedure too expensive to be practical. A further disadvantage was the fact that in using it many other marine organisms also were killed.

METHODS

Experiments on the destruction of starfish by the use of calcium oxide, or quicklime, have been carried on since 1937 at Milford Laboratory (Loosanoff and Engle 1938). The possibility of using calcium oxide for combating starfish was first suggested by Wood (1908), who recommended the building of a barrier around the oyster beds by placing lime on the bottom in paper bags. In the course of time the water would disintegrate the bags, thus exposing the lime. The caustic nature of lime would prevent starfish from crawling over the barrier. Wood's method was primarily devised to restrict the movement of starfish from one area to another, but not to exterminate them.

The new method consists of spreading the lime uniformly over the starfish-infested bottoms. As demonstrated by observations of Loosanoff (1937), starfish are slow-moving animals, staying in approximately the same places for long periods. Therefore, starfish on the treated areas cannot move to untreated areas rapidly enough to avoid contact with the lime.

At present, various devices are being developed by oystermen and by lime-manufacturing companies for releasing the lime near the bottom and for its uniform distribution over the treated areas.

Figure 1 shows in detail the apparatus suggested by the authors, which is based upon features taken from several different devices. Granulated lime is placed in the hopper (A) which is capable of holding several bags of material. By opening the trap door (B) dry lime enters the mixing chamber (C) where a strong stream of water produced by the pump (D) keeps the falling lime particles in suspension and forces the mixture through the hose line (E) to the distributing pipe (F). The efficiency of the apparatus may be increased further by placing a second pump on the other side of the mixing chamber. The hose line (E) is attached to the towing chain (J) by a series of metal rings that keeps the line from forming sharp bends, or kinks, which would interfere with the normal flow of the lime and water mixture. The towing chain is attached to a

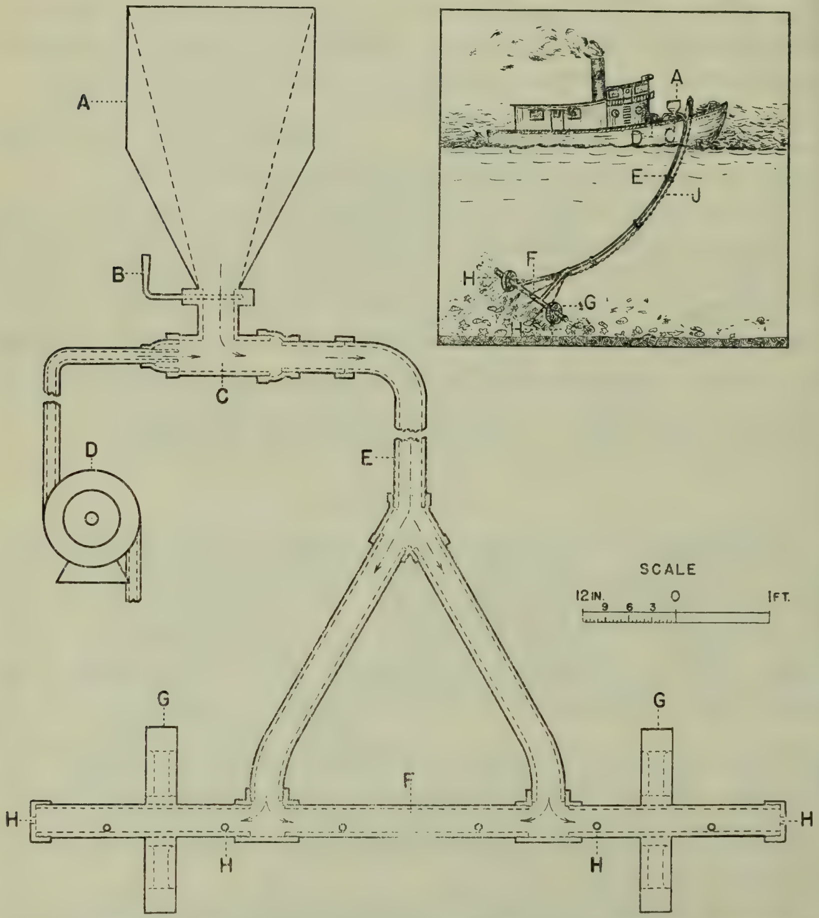

FIGURE 1.—Diagram of apparatus for spreading lime on starfish-infested bottoms.

regular dredge hoist by means of which the chain and hose line can be paid out to a desired length. The distributing pipe (F) is perforated with several holes (H), ¾-in. in diameter, through which the lime suspension is forced upward and backward in geyserlike jets. In some cases it may be advantageous to perforate the distributing pipe with horizontal slits several inches long and about ¾-in. wide in lieu of the round holes. The holes (H) of the distributing pipe (F) should be so situated that they can direct the jets of lime upward and backward. Such position of the holes will permit a more uniform dispersion of lime particles before they settle to the bottom. A pair of wheels, or skids (G) are attached to the distributor to keep it between 1 and 3 feet off the bottom.

ACTION OF LIME ON STARFISH

The effectiveness of the method depends upon the direct contact of lime with the body of the starfish. Particles of lime fall upon the surface of the starfish and imbed themselves in the membrane covering the animal. The action of lime disintegrates the delicate membrane and creates lesions. The lesions increase rapidly in size, involving the branchiae and other structures on the dorsal surface of the starfish. After several days the lesions penetrate the body walls. When this stage is reached the internal organs of the animal become exposed and death usually follows very shortly.

Starfish which are not hit directly by the lime during application will eventually come in contact with it when crawling over the bottom. Since the chemical retains its effectiveness for some time, very few starfish will escape its action. In the course of time the lower, or oral surface of these animals will become affected, and disintegration will then set in.

HEALING OF WOUNDS

It was noted that not all the starfish affected by lime died. On the contrary, cases were recorded when the wounds healed and injured structures regenerated. To observe the recovery of starfish from wounds caused by lime, several experiments were performed. One experiment was conducted to determine whether a starfish will autotomize a ray affected by lime. In this experiment 5 starfish were placed in an aquarium with running water, and a small piece of lime was placed on 1 ray of each animal. After several hours the lime was removed. Burned spots had formed on each ray treated. Soon after the beginning of the experiment 4 of the starfish displayed shallow wounds, and the fifth animal had a deep wound that penetrated the body wall. Parts of the digestive gland protruded from this wound. The starfish were kept under observation for a period of 2½ months. During that time none of them died, and not a single case of autotomy occurred. About 3 weeks after the beginning of the experiment, wounds on several starfish began to show signs of healing. The healing process, however, was very slow. Scar tissue that formed over the affected areas persisted for a long time.

Another experiment with 6 starfish was begun on Feb. 1, 1938. As in the previous experiment, 1 ray of each starfish was treated with lime. In this case, however, larger quantities of the chemical were used. Within 2 days after treatment large wounds were formed on the rays touched with lime. Several days later the wounds penetrated the body walls, exposing the internal organs. Soon 3 starfish disintegrated and died. The other 3 survived and began to show signs of healing after a period of several weeks. Regeneration proceeded quite slowly. By the end of August, almost 7 months after the beginning of the experiment, the wounds healed, but microscopic examination revealed that the areas affected possessed smaller numbers of spines, pedicellariae, and branchiae than the corresponding normal areas. Some of the newly formed spines showed definite deformities.

Many cases of healing of wounds and of recovery were noted on the starfish brought to the laboratory from the natural oyster beds where the lime treatment was tried. It appeared that recovery depends upon the number and character of wounds suffered by each individual, as well as upon escape from attack by other animals. Numerous observations made in the course of this work showed that affected starfish, especially those having their internal organs protruding through the body walls, were attacked and eaten by healthy starfish and by other animals, chiefly crabs.

It was also noted that seriously affected starfish stopped feeding and moving, while lightly affected individuals continued to move and feed quite normally. In several instances wounded animals also were observed in the act of spawning.

ERADICATION EXPERIMENTS

LABORATORY STUDIES

To test the efficiency of lime treatment, laboratory studies were carried on in large outdoor tide-filling concrete tanks and in laboratory aquaria of 15-gallon capacity. Experiments in the tanks were begun in winter, when the water temperature was at or near the freezing point, and were continued until summer. Experiments in the aquaria were usually carried on at room temperature, ranging from 17 to 20° C. Unless otherwise stated, the water in the aquaria was not changed during the run of an experiment. Because the lime was obtained in barrels, each containing 280 pounds, the experiments were conducted on the basis of a certain number of barrels per acre, with correspondingly small quantities used in the tanks and aquaria.[1]

The first series of experiments was conducted to establish the relative effectiveness of finely granulated and coarse grades of quicklime, and to determine the concentration of lime needed to kill starfish. One experiment was begun on Dec. 17, 1937, in a tank 10 feet wide and 20 feet long in which 20 starfish were placed. A quantity of lime corresponding to 3 barrels (840 pounds) per acre was then spread over the bottom. The lime used in this experiment was of a coarse grade, the bulk of which consisted of lumps ranging in size from 0.5 to 5.0 cm., but also containing finer particles resulting from crumbling.

Examination 48 hours after the beginning of the experiment showed that the membranes of the animals hit by lime particles were disintegrating, numerous large and small lesions having formed on the aboral surfaces. In the parts affected many pedicellariae and tubular branchiae were destroyed, and spines were devoid of membrane covering.

At the end of the experiment the tank was emptied and the condition of starfish noted (table 1). Of the original 20 starfish, 10 were dead and decomposed (pl. 1, upper). All these animals had large lesions on their aboral surfaces which were inflicted by particles of lime imbedded in the membranes. The 10 starfish which survived were either slightly affected or not affected at all. The slightly affected animals had only a few small lesions on their aboral surfaces, the extent of injury depending upon the number and size of lime particles which had touched them. In some cases the ends of the rays and lower surfaces of the starfish were burned (pl. 1, lower). Apparently these starfish came in contact with the lime while crawling on the bottom. The healthy animals which were not hit by falling bits of lime crawled up the walls of the tank soon after the beginning of the experiment and remained there throughout its duration, thereby avoiding contact with the chemical.

The temperature of the water in the tank during the experiment was near 2.0° C. Before the addition of lime the pH of the water was 8.0. After the addition of lime it rose to 8.2 and remained at that level for 24 hours, after which it decreased to 8.0.

From the above-described experiment it can be concluded that only those starfish that came in contact with the lime were affected. A coarse grade of lime, when used at a concentration of 840 pounds per acre, did not cover the bottom evenly, permitting many starfish to escape. All starfish injured in the experiments were affected by particles of lime falling on their aboral surfaces or by coming in contact with the lumps lying on the bottom. The change in pH produced by adding a large quantity of lime to the water was not radical enough to create conditions which would kill starfish.

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[1] Lime used in most of the experiments was furnished through the courtesy of the New Brunswick Laboratories, Inc., New York City. When delivered, it contained about 93 percent of available calcium oxide.

Simultaneously, a similar experiment was conducted in an adjacent tank in which granulated lime was used. After placing 20 starfish in the tank, the lime was spread over the surface of the water at a concentration of 840 pounds per acre. The particles of lime covered the entire bottom of the tank, and therefore fell on every starfish. Examination of starfish 24 hours after the beginning of the experiment showed many small fragments of lime imbedded in their aboral surfaces, causing disintegration of the membrane. Numerous small wounds were already visible. On the oral surfaces all the structures, including the tube feet, were seriously injured by crawling over the lime. The tube feet were abnormally slimy and their epidermal covering was disintegrating and peeling off. A few individuals had moved a short distance, but the majority remained in the same position as at the beginning of the experiment.

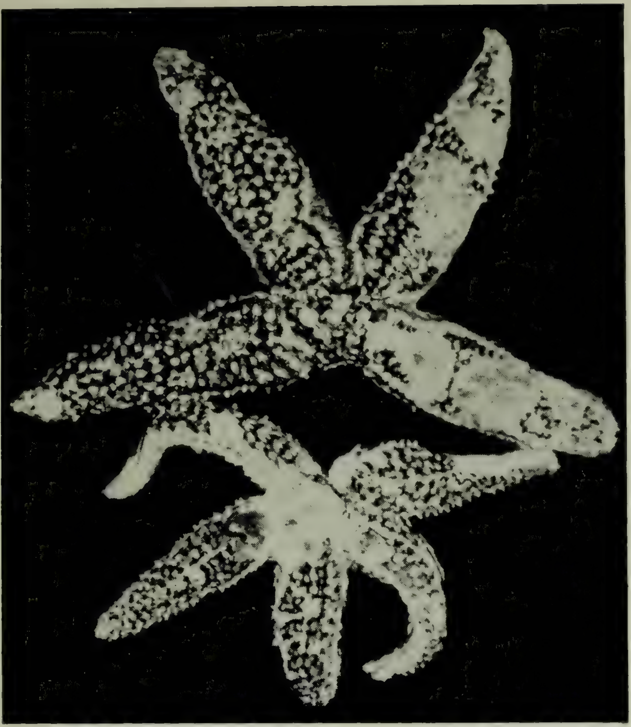
TABLE 1.—*Effect of lime upon starfish; number and day of death*

[20 starfish were used in each experiment]

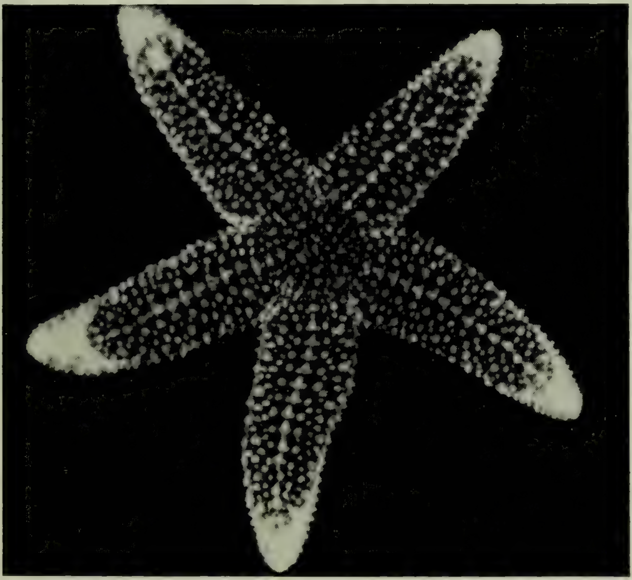
Concentration (pounds per acre) and grade of lime	Condition of test specimens								
	First day	Second day	Third day	Fourth day	Fifth day	Sixth day	Eighth day	Tenth day	Twelfth day
840 pounds [1]	--------	--------	--------	--------	2	1	2	4	1
840 pounds [2]	(3)	(4)	6	7	3	4	--------	--------	--------
560 pounds [2]	(3)	(4)	3	4	10	2	1	--------	--------
280 pounds [2]	(3)	(4)	1	2	9	8	--------	--------	--------
Control	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)

[1] Coarse. [2] Granulated. [3] All injured. [4] Many disintegrating. [5] Alive

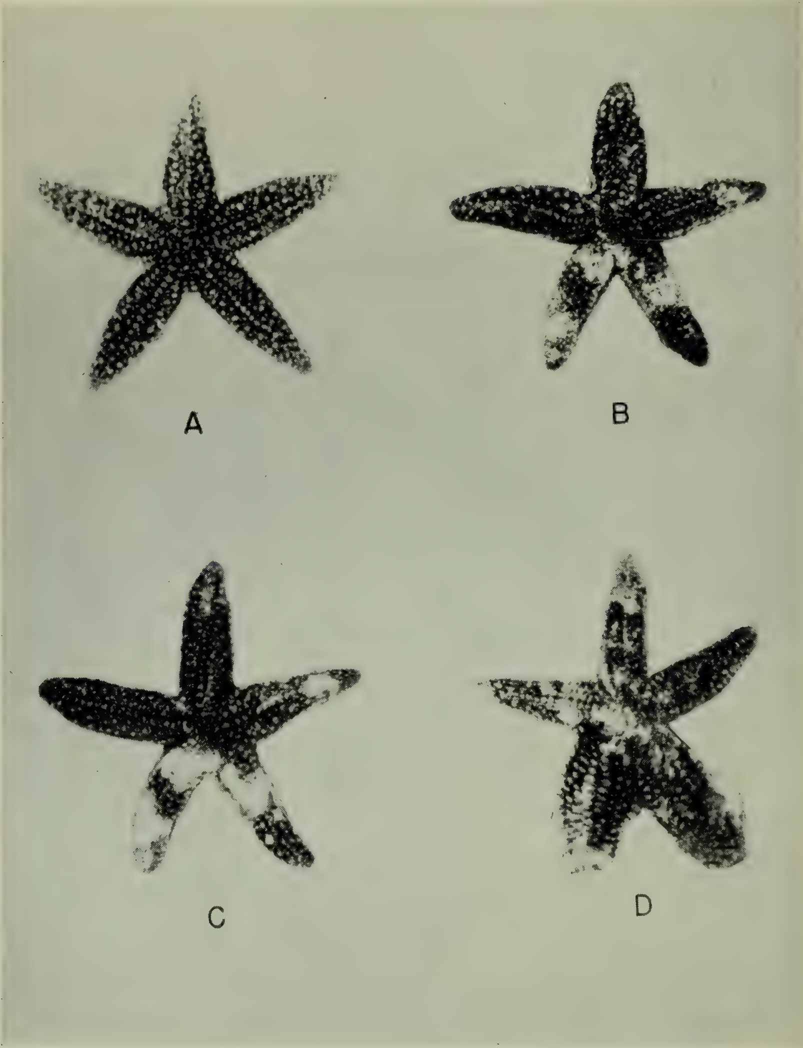
At the end of the second day the color of the starfish had changed to pale red, resembling that of a cooked lobster, and the aboral surfaces showed many destroyed pedicellariae and branchiae. The ambulacral grooves and spines on the oral surfaces were covered with white spots caused by contact with the lime. The tube feet were severely burned. Many animals began to disintegrate while still alive, and disintegration progressed still further the next day (pl. 2). At the end of 5 days 16 starfish had disintegrated completely and died, while the 4 others died on the sixth day. This experiment demonstrated that finely granulated lime covered the bottom more evenly than the coarse grade and was, therefore, more effective in exterminating starfish.



tarfish in advanced stages of disintegration, showing aboral surfaces affected by lime. Note large wounds penetrating the body walls and exposing internal organs.



Starfish with tips of rays affected by crawling over lime-covered bottom.



Effect of granulated lime on a starfish. A, normal animal; B, immediately after being touched with lime particles; C, same animal 1 day later; D, same animal (3 days after beginning of experiment) in advanced stage of disintegration.

The water temperature in the tank during this experiment was near 2.0° C. Before the addition of lime the pH of the water was 8.1 and it rose to 8.5 after the addition. A day later it decreased to 8.3, as compared with 7.9 of the control tank. Two days later the pH of the water in the experimental tank decreased to 7.9.

The experiments outlined above were repeated several times, and the results were similar to those described.

Having established the fact that lime will kill starfish, and that under the conditions of the experiment granulated lime is more efficient than coarse, a series of experiments was run to determine the minimum quantity of lime necessary to kill starfish.

Several experiments in which the lime concentration corresponded to 2 barrels (560 pounds) per acre gave results essentially the same as in the experiments in which 3 barrels per acre were used (table 1).

In the next series of experiments a concentration equal to 1 barrel per acre was employed (table 1). Twenty starfish were placed on the bottom of the tank and lime was spread evenly over the entire water surface. Examination of the starfish 24 hours after the beginning of the experiment showed that all animals were hit by particles of lime. Their aboral surfaces were badly burned, but they were still alive. At the end of the second day the starfish began to disintegrate. One animal died during the third day. After 5 days 12 starfish were dead and the others were either near death or seriously injured and partially disintegrating. When the tank was emptied 3 days later all starfish were decomposed. This experiment demonstrated that even as light a concentration as 280 pounds per acre is very effective, provided the lime is uniformly distributed over the entire area of the infested bottom.

A number of check-ups on these experiments were conducted in the laboratory, using aquaria of 15-gallon capacity. Quantities corresponding to 1, 2, and 3 barrels per acre of finely granulated lime were tried. In all these tests the starfish were quickly killed. Even when the lightest concentration was employed starfish began to disintegrate within 24 hours, and were dead by the third day.

The rapid disintegration and death of starfish in the aquaria experiments can be attributed to the two following factors: First, because the lime was very evenly distributed over the bottoms of the aquaria, all starfish were covered with the chemical; and second, the water temperature in the aquaria was near 20.0° C., and the process of disintegration of starfish progressed more rapidly than in the outside experimental tanks where a much lower temperature prevailed.

As previously mentioned, the experiments performed indicate that the contact of lime with the surface of the starfish's body was necessary to cause injury. It appeared that lime in solution was virtually harmless to starfish. To solve this question definitely, new experiments were devised and conducted under laboratory conditions. Five starfish were placed on the bottom of an aquarium and immediately covered with powdered lime at a concentration of 1 barrel per acre. As soon as the lime settled on the bottom another group of starfish, confined in a wire cage, was placed in the aquarium. The cage was suspended in the water about 3 inches from the bottom. In this way the caged animals, while exposed to lime in solution, were kept from direct contact with the solid particles.

Examination of the starfish 24 hours after the beginning of the experiment revealed that all those on the bottom of the aquarium and in contact with lime were badly affected, whereas those in the cage were healthy and normal in appearance. At the end of 48 hours, the starfish on the bottom of the tank showed signs of disintegration. They all died between the fourth and fifth days after the beginning of the experiment. The caged animals, on the other hand, were healthy and feeding upon seed oysters placed in the cage. In a final examination made 1 week after the beginning of the experiment the caged animals showed no ill effects from the treatment.

The water temperature during the experiment fluctuated from 17.5 to 20.0° C. Before the addition of lime the pH of the water was 7.9. It rose to 8.5 after lime was added and remained at this point for 2 days, dropping to 8.3 after 5 days.

Several other experiments of a similar nature were conducted and gave virtually the same results. In one of these experiments starfish were exposed to a lime solution for a period of 20 days and came out alive, though somewhat weakened. It may be concluded that a strong lime solution does not kill starfish exposed to it, even if the period of exposure is as long as 20 days. It is apparent, therefore, that the method of combating starfish with lime will be effective only if there is an actual contact between the particles of lime and the body of the starfish.

To learn how long the lime retains its efficacy in the water, the following experiments were performed: Quicklime at a concentration of 3 barrels per acre was placed in the tank on Dec. 17, 1937, and left there until Dec. 28. The chemical was quite evenly distributed on the bottom. Of course, the lime was soon changed into slaked lime, or calcium hydroxide. The water in the tank was partly renewed at each high tide. During the experiment a thin layer of organic deposit was formed over the layer of lime. At the end of the 11-day period the tank was carefully drained without losing any lime, and then refilled on the next high tide. The old lime was agitated to distribute it evenly over the bottom of the tank. After it had settled, 25 starfish were placed in the center of the tank.

The first examination of these starfish was made on Jan. 1, 1938, 4 days after the beginning of the experiment. All starfish were still alive but showed slight injuries, especially on their oral surfaces. The second examination, conducted 2 days later, revealed that 2 starfish were seriously injured. On Jan. 5, 8 days after the beginning of the experiment, 6 starfish were dead. Two more starfish died within the next 2 days, and all starfish were dead at the end of 18 days.

During this experiment the temperature of the water in the tank was between 0.0° and 2.0° C. At times a thin layer of ice formed on the surface of the water.

This experiment showed that granulated lime retains its effectiveness after being in the water 11 days. However, its action is weaker than that of unslaked lime.

A similar experiment was conducted using a coarse grade of lime. After being in the water for several days the lime was agitated and the large lumps were broken into small pieces to cover the bottom of the tank. The results of this experiment were substantially the same as when granulated lime was used, although the coarse lime was found to retain its effectiveness somewhat longer than the finer material. In both experiments the injuries to starfish were confined largely to the oral surface.

In another experiment the lime was retained in the tank for a period of 25 days. At the end of this period the lime was stirred, and while it was still in suspension 20 starfish were placed in the tank. This step was taken in order to determine the effect of old lime on the oral surface of starfish, as was done in the two previous experiments, and also on the aboral surface. The temperature during the experiment was near the freezing point and the pH was between 7.9 and 8.0, the same as the control tank. Starfish examined 4 days after the beginning of this experiment were alive, but showed small lesions on their oral and aboral surfaces. Gradually the wounds increased in size, and after 2 weeks many starfish were in advanced stages of disintegration. The first few starfish died after several days. At the end of 30 days the tank was emptied and starfish examined. Of the 20 animals, 11 were dead and decomposed, and most of the remaining 9 were seriously affected and near death. This experiment demonstrated that lime kept in the water for 25 days was still injurious to starfish, in some instances causing their death.

That a thin layer of lime putty spread on the bottom upon which tarfish are crawling may injure them was ascertained under several aboratory conditions. Almost immediately after coming into contact with the putty the starfish displayed pronounced signs of distress. They attempted to elevate themselves on the tips of their rays but soon ipped over, began to bleed profusely, and died within 3 or 4 days.

In another series of experiments small quantities of putty were smeared on the aboral surfaces of starfish, and the animals were immediately returned to tanks filled with untreated sea water. Examination of starfish 24 hours later showed that the areas of their bodies touched with putty were slowly disintegrating, exposing the internal organs.

A suspension of hydrated lime poured over the surface of the water-filled tank can also be used in killing starfish. It was found that under this condition the particles of lime slowly settle down, covering the starfish with a thin layer. The majority of the starfish thus treated died within a few days.

According to the results obtained from the above experiments, hydrated lime will injure starfish if it comes in contact with them. Apparently the caustic action of the hydroxide is strong enough to produce a wound and cause disintegration of the affected tissues and adjacent parts of the body.

FIELD EXPERIMENTS

Field experiments in starfish eradication on natural oyster beds of Long Island Sound were carried on during the spring of 1938. Unfortunately no proper equipment for uniform spreading of lime was available at that time. The lime was either shoveled, or washed overboard with a strong jet of water. In this way the distribution of lime over the areas treated was far from uniform. Another difficulty in using such primitive methods was that tidal currents carried the lime particles quite a distance away before they reached the bottom. This was overcome in some instances by spreading lime during slack-water stages. However, because slack water in Long Island Sound is of short duration, this practice could be followed only when small areas were treated. Regardless of adverse conditions, however, all field experiments revealed that by using lime starfish can be successfully attacked.

In the first series of experiments 2 lots, A and B, each 1 acre in area and located 500 feet apart, were chosen. These lots constitute a part of the Stratford natural oyster bed, located in 25 feet of water. On Mar. 11, 1938, 840 pounds of granulated lime were spread on lot A, and the same quantity of coarse material was deposited on lot B.

Samples of starfish collected the day after treatment (table 2) showed that although many animals of both lots were affected, their wounds were still very small and difficult to see. The animals were rigid and comparatively healthy. Seven days after the treatment 58 percent of starfish retrieved from lot A, and 84 percent from lot B were found to be affected. By that time the lesions were large, covering the greater part of the aboral surface. The wounds penetrated the body walls, and the internal organs of many protruded. Many starfish were dying or were already dead. Samples collected 13 days after the treatment showed 78 percent of animals from lot A, and 71 percent from lot B affected. Again the majority of animals were badly wounded, many of them disintegrating and dying. On the eighteenth day after the treatment 50 and 52 percent of starfish with wounds were found at lots A and B, respectively. However, the majority of animals had only small wounds. Apparently the starfish that were seriously affected had already died, and thereafter a further decrease in the percentage of injured animals was noted. This was due partly to the invasion by new starfish from the adjacent untreated grounds, to the death of some of the wounded animals, and, also, to recovery of the slightly injured animals. Starfish with scars caused by contact with lime were found as late as May 10, 2 months after the lime was used.

TABLE 2.—*Temperature and pH of water, and numbers and percentage of affected starfish on lots A and B, Stratford natural bed, treated on Mar. 11, 1938, with 840 pounds of lime per acre*

[Granulated lime was used on lot A, and a coarse grade of lime on lot B]

Date	Temp. °C.	pH	Lot A			
			Number examined	Number affected	Number not affected	Percent affected
Mar. 11	1.4	[1] 8.3				
11	1.4	[2] 8.5				
12	1.5	8.3	32	16	16	50
18	2.4	8.3	26	15	11	58
24	3.3	8.3	23	18	5	78
29	3.6	8.3	48	24	24	50
Apr. 6	3.8	8.3	50	21	29	42
16	6.1	8.2	45	11	34	24
26	8.3	8.1	69	15	54	22
May 10	11.9	8.3	40	6	34	15

Date	Temp. °C.	pH	Lot B			
			Number examined	Number affected	Number not affected	Percent affected
Mar. 11	1.4	[1] 8.3				
11	1.4	[2] 8.5				
12	1.5	8.3	13	5	8	38
18	2.4	8.3	13	11	2	84
24	3.3	8.3	35	25	10	71
29	3.6	8.3	52	27	25	52
Apr. 6	3.8	8.3	85	22	63	26
16	6.1	8.2	52	16	36	31
26	8.3	8.1	40	6	34	15
May 10	11.9	8.3	39	8	31	21

[1] Before addition of lime.

[2] Fifteen minutes after addition of lime.

The results of the experiment are somewhat different from those carried on under laboratory conditions in that the treatment with a coarse grade of lime affected about the same percentage of starfish as did granulated lime. This discrepancy can be explained by the fact that under the conditions of the test a large quantity of fine particles were carried far away by the tide before they reached the bottom.

Thus, much lime intended for lot A was lost. On the other hand, coarse particles of lime used for lot B sank rapidly to the bottom, causing a much heavier concentration than that obtained on lot A.

Another experiment in this series was begun on Mar. 14, 1938, near Charles Island. Two widely separated lots, each 1 acre in area and located at a depth of about 18 feet, were treated with lime. Lot C received 840 pounds, and lot D 280 pounds of granulated lime. In treating these 2 lots extreme care was taken to distribute the chemical as uniformly as possible. To make sure that the lime would not be carried away by the currents while sinking to the bottom, the treatment was conducted during slack-water period. Samples collected 10 days after the treatment showed that 88 percent of starfish from lot C, and 74 percent from lot D, were affected (table 3). It should be borne in mind, however, that by the time the examination was made many starfish from adjacent untreated areas had crawled over to the experimental lots. Their presence in the collected samples undoubtedly decreased the percentage of affected starfish.

TABLE 3.—*Temperature and pH of water, and numbers and percentage of affected starfish on lots C and D, treated with granulated lime on Mar. 14, 1938*

[Lot C received 840 and lot D 280 pounds of lime per acre]

Date	Temp. ° C.	pH	Lot C			
			Number examined	Number affected	Number not affected	Percent affected
Mar. 14	2.0	[1] 8.3				
14	2.0	[2] 8.5				
18	2.5	8.3	8	6	2	75
24	3.3	8.3	8	7	1	88
29	3.6	8.3	15	12	3	80
Apr. 6	3.9	8.3	16	3	13	19
16	6.8	8.3	6	6	0	100
19	7.4	8.1	18	4	14	22

Date	Temp. ° C.	pH	Lot D			
			Number examined	Number affected	Number not affected	Percent affected
Mar. 14	2.0	[1] 8.3				
14	2.0	[2] 8.5				
18	2.5	8.3	6	4	2	67
24	3.3	8.3	23	17	6	74
29	3.6	8.3	11	4	7	36
Apr. 6	3.9	8.3	20	3	17	15
16	6.8	8.3	5	2	3	40
19	7.4	8.1	20	4	16	20

[1] Before addition of lime.

[2] After addition of lime.

The third test in this series was conducted on a much larger scale on seed-oyster grounds located in New Haven Harbor. On Mar. 22, 1938, 3 oyster lots were treated with granulated lime. Lot No. 1, comprising an area of 25 acres, located at a depth of approximately

17 feet, received 320 pounds of lime per acre. Lot No. 2, of the same size as the first lot, and located at approximately the same depth, received 480 pounds of lime per acre. Lot No. 3, 15 acres in area, located in 25 feet of water, was treated with 640 pounds of lime per acre. The lime was applied by forcing it overboard with a strong stream of water. Because of limited time, the work of spreading the lime had to be carried on regardless of direction and velocity of tidal currents. Much of the lime, therefore, was carried by the currents beyond the areas intended for treatment.

TABLE 4.—*Temperature and pH of water, and numbers and percentage of affected starfish on lots 1, 2, 3, New Haven Harbor, treated with granulated lime on Mar. 22, 1938*

Date	Temp. ° C.	pH	Number examined	Number affected	Number not affected	Percent affected
			Lot 1, depth 17 feet, 320 pounds of lime per acre			
Mar. 22	3.6	8.3	---	---	---	---
29	3.8	8.3	178	103	75	58
Apr. 1	4.4	8.3	180	89	91	49
5	5.3	8.3	98	46	52	47
12	5.1	8.3	169	60	109	36
19	7.8	8.2	12	4	8	33
26	9.1	8.2	6	2	4	33
May 3	11.3	8.3	6	0	6	0
10	10.9	8.3	12	3	9	25
			Lot 2, depth 17 feet, 480 pounds of lime per acre			
Mar. 22	3.5	8.3	---	---	---	---
25	2.6	8.1	26	20	6	77
29	3.9	8.2	168	133	35	79
Apr. 1	4.5	8.3	146	100	46	68
5	5.5	8.3	149	69	80	46
6	---	---	113	91	22	81
12	5.1	8.3	146	84	62	58
19	7.8	8.2	69	36	33	52
26	9.2	8.3	98	58	40	59
May 3	11.2	8.3	15	8	7	53
10	11.0	8.3	24	14	10	58
			Lot 3, depth 25 feet, 640 pounds of lime per acre			
Mar. 22	2.7	8.3	---	---	---	---
25	3.2	8.3	115	75	40	65
29	3.8	8.3	72	46	26	64
Apr. 1	4.8	8.3	142	51	91	36
5	5.3	8.3	66	27	39	41
12	5.0	8.4	215	92	123	43
19	7.0	8.3	3	1	2	33

After the treatment all three lots were visited frequently, and samples of starfish were collected and the number of injured animals noted (table 4). The best results were observed at lot No. 2, where, in some samples, the percentage of affected starfish was as high as 81. Lot No. 3 was second best, with 33 to 65 percent of the starfish affected.

The percentage of starfish affected at lot No. 1 reached 58 in some samples.

Seriously affected starfish died within a few days after the treatment. Less seriously wounded animals could be found on the beds for a long time after the treatment. In some cases healing of wounds was observed. Experiments performed on Charles Island beds showed that even a small quantity (280 pounds per acre) of lime, if spread uniformly and under the proper tidal conditions, will destroy the majority of starfish present. On the basis of these and other field experiments it was concluded that lime is an effective agent for the eradication of starfish on natural oyster bottoms. The efficiency of the treatment undoubtedly depends upon the uniformity of distribution of the chemical over the bottom, and upon the quantities used.

Field studies of the authors were corroborated by several oyster-growing concerns. Joseph B. Glancy, of Bluepoints Company, Inc., West Sayville, Long Island, N. Y., in a letter to the authors, stated that the results obtained by him were distinctly encouraging. An oyster bed of about 40 acres in area, located in Huntington Bay, N. Y., was treated on Apr. 8, 1938. The depth of water over the bed varied from 10 to 40 feet. At the time the lime was applied, the bed had over 15,000 bushels of oysters ranging from 2 to 4 years of age. Prior to the application of lime, starfish were very numerous, comprising about one bushel out of every 25 bushels of material dredged from the bottom.

In treating the bed, 480 pounds of lime per acre were spread on the surface of the water. One week later 90 percent of the starfish captured were found to be affected, and many starfish, especially the larger ones, were disintegrating. Such results were apparent over the entire bed. The oysters and other bottom forms apparently remained unharmed and the mortality of oysters due to starfish activity had almost ceased. The second examination of the bed, 17 days after the application of lime, showed that the number of starfish had significantly diminished; only about 20 percent of the original population remaining. About 1 year after the lime treatment the oysters were dredged and marketed. According to Glancy, their meats were in excellent condition.

EFFECT OF LIME ON ANIMALS OTHER THAN STARFISH

The question naturally arises as to how lime used in large quantities on starfish-infested bottoms will affect other animals. Since oysters and other shellfishes constitute the most important branches of commercial fisheries in Long Island Sound, attention was directed mainly upon these animals, with a few additional observations on other forms.

SURVIVAL AND GROWTH OF OYSTERS

As a rule, in all laboratory and tank experiments with lime, marine forms, including oysters, were kept under the same conditions as the starfish. No unusually high mortality among oysters was noted during any of the experiments, nor after the experiments were concluded and the oysters were returned to a normal environment. In the field, oysters dredged from bottoms treated with lime always appeared healthy. Apparently the addition of lime in the quantities employed in our experiments did not cause serious injuries. However, to obtain some definite information on the survival of oysters when exposed to the effects of lime, and also on their growth, weight increase, rate at which water is pumped, and other physiological activities, several experiments were performed.

On May 16, 1938, 100 normal oysters about 3 years old were individually marked, measured, and weighed. The animals were divided into two groups of 50 individuals, and each group was placed in a separate outdoor tide-filled tank of several thousand gallons capacity. The water in the tanks was partly renewed at each high tide. During low tides the oysters in the tanks were covered by about 3 feet of water. At the beginning of the experiment, lime at a concentration of 5 barrels, or 1,400 pounds, per acre was added to the experimental tank. Each month throughout the experiment a new dose of lime was thrown in the tank. Such an excessive quantity of lime was used as to create a concentration greater than would probably ever be employed on the oyster beds. Unfavorable conditions in the tank were further aggravated by depriving the oysters of the beneficial effects of the rapidly running tide, which on the natural beds would soon dilute the solution of lime to a negligible concentration. Thus the animals in the experimental tank were subjected to much more severe conditions than they would be in open water treated with the same concentration of lime. Except for the addition of lime, the conditions in the experimental and control tanks were identical.

The experiment was continued from May 16 until Nov. 1, 1938. Every month all animals were measured and weighed. At the beginning of the experiment the average maximum length of animals in the lime tank was 72.17 mm., as compared with 73.10 mm. for those in the control tank, showing a difference of 0.93 mm. in favor of the control group (fig. 2). At the end of the experiment, 5½ months later, the average maximum length of lime-treated animals was 83.66 mm., whereas that of the control was 86.10 mm., or 2.44 mm. more. Thus, in this experiment the control animals showed a slightly better growth than the group subjected to lime treatment. It should be emphasized, however, that regardless of abnormal conditions existing in the lime tank, the growth of the oysters kept there was neither stunted nor considerably retarded. This is shown by the fact that the average maximum length of these animals increased during the experiment from 72.17 to 83.66 mm., or 11.49 mm. In the same time the control group showed an increase from 73.10 to 86.10 mm., or 13.00 mm. During a 5½-month period the lime-treated animals grew on an average only 1.51 mm. less than animals kept under normal conditions. The new shell growth of lime-treated oysters appeared normal and undistinguishable from that of control animals.

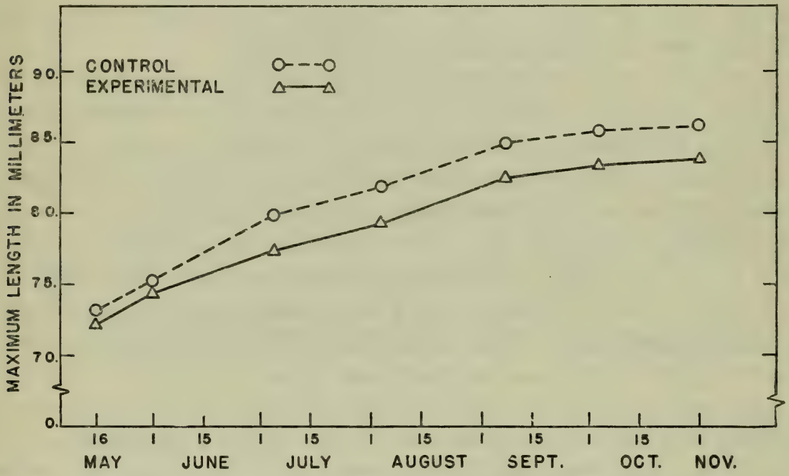


FIGURE 2.—Increase in size of lime-treated and control oysters. May 16 to Nov. 1, 1938.

Studies of changes in the weight of the two groups of oysters showed that the average total weight of lime-treated animals changed during the time of the experiment from 67.10 to 100.47 g., an increase of 33.37 g. (fig. 3). The average weight of the control animals increased during the same period from 69.24 to 112.91 g., giving an increase of 43.57 g.; or 10.30 g. greater than for the experimental group. Such a difference is quite significant, showing that conditions existing in the lime-treated tank interfered with the normal increase in weight of the oysters.

More detailed studies of changes in the size and weight of the two groups of oysters showed that the difference between the lime-treated and control animals became more pronounced as the experiment progressed (figs. 2 and 3). This can be attributed either to the cumulative effect of lime on the oysters themselves, or to the fact that the large quantities of lime always present in the experimental tank decreased the numbers of microscopic organisms normally present in the water, thereby depriving the oysters of their normal quota of food. During the experiment 2 oysters in the control tank, and 4 in the lime-treated tank, died.

At the end of the experiment all surviving oysters were killed and their meats and shells weighed. The average weight of the meat of lime-treated animals was 10.69 g., and that of their shells 78.9 g. Control animals gave 13.96 and 85.8 g. for meats and shells, respectively. For the lime-treated group the weight of meat constituted 10.6 percent, and the weight of shell 78.3 percent of the total weight. In the control group these percentages were 12.4 and 75.9.

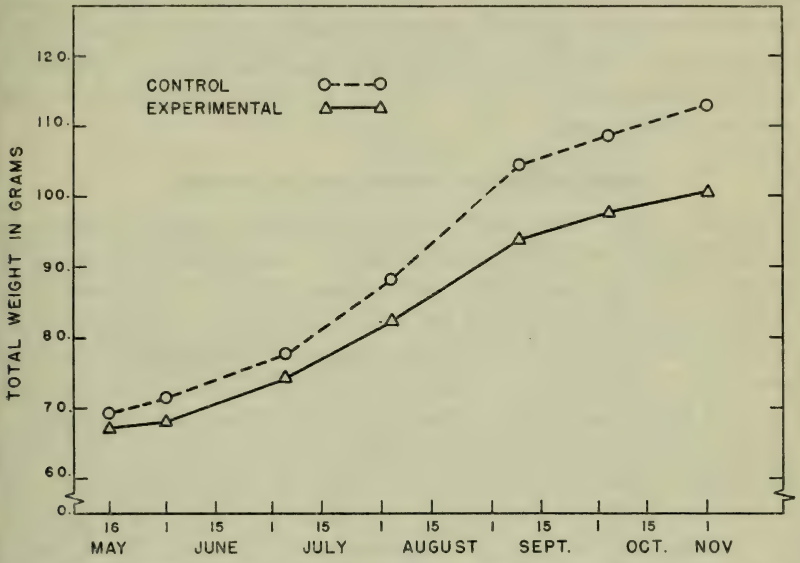


FIGURE 3.—Increase in weight of lime-treated and control oysters. May 16 to Nov. 1, 1938.

To summarize the above-described experiment, it may be stated that the majority of oysters subjected to a very strong concentration of lime for a period of 5½ months survived the treatment, but their growth and increase in weight was somewhat retarded. It should be remembered, however, that the concentration of lime in the tank was much greater than that to be expected on natural beds. Furthermore, such a strong concentration of lime persisted in the tank for months, whereas in a large open body of water a strong concentration could persist for only a few minutes because the tidal currents would soon dilute it. It is apparent, therefore, that the use of moderate quantities of lime in combating starfish cannot endanger the oysters on the treated area.

The experiment just described brought to light another fact which is of interest to commercial oystermen. It has been claimed that if green oysters, which are very common in Long Island Sound, are treated with lime simply by spreading it over the oyster bottom, they will lose their greenness and acquire a normal creamy color. Our experiments have shown that such statements cannot be supported. Oysters used in our experiments were brought from Stratford natural beds, known for its green oysters. After being kept in the tank containing lime for 5½ months, oysters were opened and their color noted. Of 46 animals examined, 27 were very green. Among the control group 25 showed green color. It is clear, therefore, that the spreading of lime upon the bottom will not whiten green oysters. This conclusion is also corroborated by our field observations. Many oysters collected at regular intervals from the beds of Long Island Sound, after treatment with lime, were green. As compared with the color of oysters of adjacent beds, the intensity of green color of lime-treated oysters was not altered.

SHELL MOVEMENT AND FEEDING OF OYSTERS

Hopkins (1932) has shown that oysters are highly sensitive to chemical changes occurring in the water. Sometimes, because of the presence of foreign substances, the number of hours the oyster keeps its shells open is reduced, and the water-pumping capacity and hence the rate of feeding are significantly decreased (Baltsoff et al. 1938). Because the new method of starfish eradication would require comparatively large quantities of lime to be introduced into the water, a possibility existed that this would seriously interfere with the normal physiological functions of oysters living on the treated beds. To establish definitely what effect the lime solutions would have upon the shell movements, feeding, and respiration of oysters, the following experiments were performed at Milford Laboratory.

Oysters used in these experiments were subjected to various concentrations of lime in sea water. The animals were mounted on small cement blocks. Their right shell valves were connected by a string to kymograph levers, which, in turn, recorded every movement of the shell on the kymograph drum.

To study the effect of solutions of lime upon feeding activities of oysters, a combination of the apron method described by Nelson (1936) and modifications of Galtsoff's constant-level-tank device were used. With such an arrangement it was possible to obtain a continuous record of the quantities of water pumped by the oysters.

To determine the normal behavior of experimental animals they were kept for long periods in running sea water before being subjected to the lime solution (table 5). To observe the recovery of oysters after their exposure to lime they were again returned to running sea water and their shell movements and other activities noted and recorded. A second group of oysters, designated as the control, was kept under conditions virtually identical to those of the experimental animals, except that no lime was added to the water.

Experimental oysters were subjected to a running saturated lime solution, to a running solution composed of 1 part of saturated lime solution and 1 part of sea water, and to a running solution of 1 part of saturated lime solution in 3 parts of sea water. Results of the experiments are summarized in table 5. Data for each of the first two concentrations represent the average of two observations. The averages for the 1:3 concentration are based upon 4 experiments.

TABLE 5.—*The effect of lime solution upon the shell movements and the quantities of water pumped by oysters*

Conditions	Duration of experiment	Average			
		Percent of time open	Water filtered, cc. per hour	pH	Temp. ° C.
1. In sea water, before treatment	55 hrs. 15 min	97.5	98.8	8.1	14.5
2. In saturated lime solution	105 hrs. 10 min	18.0	6.9	9.5	16.2
3. Recovery in sea water	35 hrs	95.5	200.2	8.1	14.9
Control 1. Sea water	43 hrs. 25 min	98.4	123.0	8.2	13.4
2. Sea water	101 hrs. 35 min	80.4	119.8	8.2	14.2
3. Sea water	48 hrs. 8 min	60.6	53.9	8.1	14.1
1. In sea water, before treatment	18 hrs. 46 min	92.5	1173.0	8.1	15.6
2. In 1 part saturated lime solution, 1 part sea water.	92 hrs. 43 min	79.5	367.0	8.8	15.3
3. Recovery in sea water	24 hrs. 17 min	68.0	1190.6	8.1	14.6
Control 1. Sea water	17 hrs. 33 min	86.8	714.9	8.2	15.7
2. Sea water	91 hrs. 43 min	93.7	1003.4	8.1	14.4
3. Sea water	24 hrs. 15 min	81.9	654.2	8.1	14.8
1. In sea water, before treatment	59 hrs. 4 min	92.7	1355.7	8.1	15.0
2. In 1 part saturated lime solution, 3 parts sea water.	215 hrs. 41 min	82.1	1385.5	8.6	15.6
3. Recovery in sea water	109 hrs. 49 min	79.5	2019.8	8.1	15.3
Control 1. Sea water	51 hrs. 56 min	92.4	1305.8	8.0	15.2
2. Sea water	216 hrs. 42 min	85.5	2048.4	8.2	15.4
3. Sea water	105 hrs. 17 min	71.5	2276.0	8.1	15.5

Oysters exposed to a saturated solution of lime kept their shells closed for a longer time and pumped much less water than before treatment. Whereas, before the treatment the oysters remained open 97.5 percent of the total time, during the treatment they were open only 18 percent. The average rate of pumping decreased from 98.8 cc. per hour before the treatment to 6.9 cc. during exposure to the concentrated lime solution.

Oysters exposed to the mixture of 1 part of lime water and 1 part of sea water remained open 79.5 percent of total time, as compared with 92.5 percent before exposure. Such a difference can hardly be considered as significant, because in the control experiment the percentage of time the shells remained open varied from 81.9 to 93.7, or about as much as in the case of lime-treated animals. Significant, however, was the observation that the average hourly quantities of water pumped by the oysters decreased from 1,173 cc. before the treatment to 367 cc. during exposure. A marked reduction in pumping activities was thus still evident.

In a concentration of 1 part of saturated lime solution to 3 parts of sea water, the oysters kept their shells open 82.1 percent of total time. This compared favorably with the observations on control animals which were open for about the same percentage of time (table 5). During exposure to the chemical, the rate of water filtration by oysters was somewhat greater than during the period before the treatment. This indicated that the ciliary activities of oysters were not depressed when the animals were exposed to a 1:3 dilution of lime water.

Generally, a quick and rather marked recovery of ciliary action was noted as soon as solutions of lime were substituted with the flow of fresh sea water. In the first series of experiments, where concentrated solutions of lime were used, the average quantities of water passed by oysters during the recovery period were more than twice greater than before the beginning of the treatment. In the second series there was also a marked increase in the rate of flow immediately after the treatment, being even slightly greater than before the oysters were subjected to the effect of the chemical. These observations suggest the attempt of oysters to cleanse themselves from the effect of the chemical. Increase in water flow produced by the oysters after exposure to lime solutions was also observed in the last series of experiments. There, however, the increase was not proportionally as large as in the two previous experiments.

As previously stated, a marked decrease in the time oysters remained open was noted as soon as they were exposed to a concentrated lime solution (table 5). Soon after the solution was replaced with running sea water, however, the shell movements of the oysters became normal. There was no definite change noted in the type of shell activity before and after exposure to the chemical. Similar observations were made in two other series of experiments where weaker concentrations of lime were used. The only exception noted in the latter cases was that during the recovery period the percentage of time the oysters remained open was somewhat smaller than before the treatment, or even during exposure period (table 5). These observations are not significant, however, because a corresponding reduction in the percentage of time open was noted in case of control animals.

The water temperature during experiments ranged from 13.0° to 16.5° C. Usually the difference in temperature of lime solution and sea water flowing over the control animals did not exceed 1 or 2 degrees, and the salinity of the water was maintained near 25 parts er mille. The pH of the sea water ranged from 8.0 to 8.25. In a aturated lime solution the pH rose to 9.5. In the second series of xperiments the pH of lime water ranged between 8.7 and 8.8, while he pH of the weakest lime solution used was near 8.6 (table 5).

After the end of laboratory experiments all oysters exposed to ime solutions were transferred to large outdoor tanks for further bservations. Fourteen months later many animals were still alive.

The physiological experiments described above demonstrated the elative safety of oysters inhabiting lime-treated areas. They showed hat oysters exposed for long periods to such strong concentrations s 1 part saturated lime solution to 3 parts sea water behaved nor-nally and displayed no ill effects. Oysters exposed to a saturated ime solution for several days survived and were alive 14 months after he end of the experiment. It should be remembered that in actual ractice the strong concentrations of lime solutions used in our xperiments will never exist in open water for any appreciable time. herefore, the lime method for the extermination of starfish can be egarded as safe for oysters.

GONAD DEVELOPMENT AND SPAWNING

The effect of lime on gonad development and spawning of oysters vas studied by keeping adult oysters in a tank to which large quan-ities of lime were added. This experiment was conducted in the ame tanks used in the experiments on growth and survival of oysters ubjected to lime, and was run simultaneously. Half a bushel of ysters was placed in each of the tanks on May 16, 1938. From hen on, at biweekly intervals, a sample of 6 oysters was taken from ach tank for histological examination of gonads. Throughout the xperiment no difference between the control and lime-treated animals ould be detected. In both cases gonad development proceeded nor-nally. Both groups of oysters began spawning at approximately the ame time.

SETTING OF OYSTERS ON LIME-COVERED BOTTOMS

To determine whether the oyster larvae would set on lime-covered ottoms, the following experiment was performed in July 1938. en bushels of oyster shells were spread on each of 2 lots, 150 square eet in area, located near mean low-water mark in Milford Harbor nd separated from each other by a distance of about 10 feet. On op of the shells wire-bag spat collectors were placed. One of the ots was covered with enough lime to form a thick layer over the ntire area. The other lot, designated as a control, was not treated. ime was spread on the experimental lot during low tide, when he lot was exposed. Our observations showed that no lime had een carried by the currents onto the control lot.

The first setting of oysters took place on July 29, 3 weeks after the lime was put over the shells. At the end of the setting period, on August 16, 50 shells were collected at random from each lot, and 25 shells from each of the wire-bag spat collectors. These shells were examined and the number of set attached to them were counted. There were 144 spat found on 50 loose shells from the lime-covered lot, as compared with 324 spat attached to the same number of shells gathered from the control lot. Thus, the set on the untreated shells was more than twice that on treated areas. However, the number of spat on 25 shells taken from the wire-bag spat collector that came from the lime-covered lot was 74, whereas the number of spat from 25 shells of the control bag was 61, or 13 less.

The considerably smaller number of oyster spat found on the loose shells of the lime-treated lot indicated that large quantities of lime deposit on the shells interfered with the normal setting of oysters. This was probably due in part to the fact that the oyster larvae could not find clean, hard areas for their attachment. Apparently the thick layer of lime on the loose shells interfered mechanically, and probably chemically, with the setting of the larvae. The observation that the shells taken at random from the wire-bag spat collector treated with lime contained more spat than the shells of the identical collector of the control lot can be explained on the ground that, since only the upper layer of shells of the collector was covered with lime, there were enough clean shells inside of the bags to provide setting areas for the spat. It should be remembered that in connection with these experiments the concentrations of lime used were far greater than those expected to be used on oyster beds, and, as will be discussed later on, the lime treatments should be used only in autumn, winter, and early spring (p. 28). Obviously, the lime will disappear by the time the setting of oysters usually takes place. Furthermore, the planting of shells for catching spat is, as a rule, conducted during June and July, or during the time when the use of lime is not recommended.

Observations on survival of seed oysters subjected to the effects of lime showed that these animals survived the treatment very well. Seed oysters lived in the tank with lime for 6 months, and at the end of that time were apparently normal. No unusual mortality was noted among seed oysters collected from the natural beds where experiments were conducted.

MOLLUSKS OTHER THAN OYSTERS

Hard clams (*Venus mercenaria*), soft clams (*Mya arenaria*), and mussels (*Mytilus edulis*), kept in the tanks to which lime at the rate of 1,400 pounds per acre was added at monthly intervals, survived such an exposure for a period of about 6 months. The mortality among these animals ranged between 4 and 5 percent, being no higher than in the control tanks. Field experiments showed also that there was no mortality which could be attributed to the effects of lime among those mollusks dredged from the beds where experiments in the eradication of starfish were conducted.

Table 6.—*The effect of lime solution upon shell movements of hard clams* (Venus mercenaria)

Conditions	Duration of experiment	Average		
		Percent of time open	pH	Temp. °C.
1. In sea water, before treatment	19 hrs. 19 min	52.8	8.1	19.6
2. In 1 part saturated lime solution, 1 part sea water.	49 hrs. 8 min	52.4	8.8	19.2
3. Recovery in sea water	35 hrs. 49 min	90.9	8.1	18.8
Control 1. Sea water	18 hrs. 59 min	44.8	8.2	19.3
2. Sea water	49 hrs. 8 min	81.9	8.1	18.5
3, Sea water	35 hrs. 49 min	88.0	8.1	18.4
1. In sea water, before treatment [1]	53 hrs. 46 min	67.3	8.1	15.0
2. In 1 part saturated lime solution, 3 parts sea water.	200 hrs. 9 min	80.9	8.6	15.4
3. Recovery in sea water	80 hrs. 21 min	84.9	8.1	15.8
Control [1] 1. Sea water	53 hrs. 46 min	76.6	8.0	15.0
2. Sea water	199 hrs. 16 min	93.8	8.2	15.1
3. Sea water	80 hrs. 21 min	93.9	8.1	15.5

[1] Average of four experiments.

Table 7.—*The effect of lime solution upon the shell movements of mussels* (Mytilus edulis)

Conditions	Duration of experiment	Average		
		Percent of time open	pH	Temp. °C.
1. In sea water, before treatment	19 hrs. 9 min	95.2	8.1	19.6
2. In 1 part saturated lime solution, 1 part sea water.	49 hrs. 8 min	96.4	8.8	19.1
3. Recovery in sea water	32 hrs. 35 min	99.0	8.1	18.7
Control 1. Sea water	18 hrs. 59 min	59.9	8.2	19.3
2. Sea water	46 hrs. 28 min	94.6	8.1	18.5
3. Sea water	35 hrs. 44 min	96.5	8.1	18.4
1. In sea water, before treatment [1]	32 hrs. 23 min	99.7	8.1	14.5
2. In 1 part saturated lime solution, 3 parts sea water.	119 hrs. 51 min	99.5	8.6	16.4
3. Recovery in sea water	54 hrs. 8 min	96.6	8.1	16.6
Control [1] 1. Sea water	18 hrs. 3 min	99.8	8.0	14.8
2. Sea water	84 hrs. 39 min	99.7	8.2	15.8
3. Sea water	54 hrs. 8 min	99.3	8.1	16.6

[1] Average of two experiments.

Observations on the shell movements of hard clams exposed to very strong solutions of lime showed that the time these animals remained open was somewhat less than for those of the control (table 6). Judging by the fact that the percentage of time they were open during exposure to concentrations of from 1:1 to 1:3 was either almost equal to or in excess of that before treatment, however, it may be concluded that the experimental animals were not much affected by lime in solution. Observations on the shell movements of the mussels revealed that they were not disturbed by the presence of lime in the water (table 7). When exposed to 1 : 1 and 1 : 3 concentrations, mussels kept their shells open virtually the same percentage of time as did the control animals. The records of all shell movements were obtained with kymographs.

Other mollusks whose behavior was observed were two species of *Crepidula*, *Anomia*, two common forms of oyster drills, *Urosalpinx cinerea*, and *Eupleura caudata*, and two species of mud snails, *Nassa*. All these animals appeared to be unaffected after exposure to saturated lime solutions in outdoor tanks for a period of 2 weeks or longer.

TABLE 8.—*Effect of three different concentrations of lime in sea water, filtered and unfiltered, on the hatching of eggs of flatfish* (Pseudopleuronectes americanus)

Concentration	Condition	Exposure time	Quantity of eggs used, cc.	Quantity of eggs unhatched, cc.	Quantity of eggs hatched, cc.
1 : 250	Filtered	3 hrs. 30 min.	50	8.0	42.0
1 : 500	Filtered	3 hrs. 30 min.	50	7.5	42.5
1 : 1000	Filtered	3 hrs. 30 min.	50	9.0	41.0
Sea water (control)			50	7.0	43.0
1 : 250	Unfiltered	3 hrs. 0 min.	50	50.0	0.0
1 : 500	Unfiltered	3 hrs. 0 min.	50	50.0	0.0
1 : 1000	Unfiltered	3 hrs. 0 min.	50	50.0	0.0
Sea water (control)			50	8.0	42.0

EGGS AND FRY OF FLATFISH

Experiments performed at Milford Laboratory and the State hatchery at Noank, Conn., showed that the eggs and fry of flatfish (*Pseudopleuronectes americanus*) may survive in strong solutions of lime, provided they do not come into contact with solid particles. Samples consisting of 50 cc. of flatfish eggs were kept in strong concentrations of lime in sea water for several hours (table 8). In the first series of experiments the solutions were filtered to remove undissolved particles of lime before the eggs were placed in it. After exposure to lime water for 3½ hours the eggs were transferred to hatching jars through which sea water was circulated. Two days after the exposure the first few fry hatched, escaping from the jar into an aquarium, and within a few days hatching was finished. The volume of all unhatched eggs was then determined (table 8). In all cases the quantities of unhatched eggs were almost identical; closely approaching that of the control.

In another series of experiments, 1 : 250, 1 : 500, and 1 : 1,000 concentrations of lime were used. Undissolved particles of lime were left in the vessel, forming a thin layer on the bottom so that the eggs came into contact with them. All eggs died (table 8).

Flatfish fry survived for 1 hour in a filtered saturated lime solution. They died quickly, however, after coming into contact with solid particles of lime.

As these experiments indicate, the eggs and fry of flatfish may be seriously endangered by the indiscriminate use of lime. It is suggested, therefore, that this chemical should not be used in the areas thickly populated with flatfish during the time when their eggs and fry are present.

LOBSTER LARVAE

Observations on the effect of lime on lobster larvae were conducted at Noank Hatchery in June 1938. The first 3 larval stages were used. The first stage was composed of animals that were about 12 hours old, those of the second stage were 8 days old, and of the third stage 14 days old. In a dilution of 1 part of a filtered saturated solution of lime tc 10 parts of sea water the larvae of all stages survived for 4 hours. The same results were obtained when a solution of 1 part of a saturated lime solution to 2 parts of sea water were used. In a solution of 1 part of lime water to 1 part of sea water, however, a mortality of about 25 percent was registered at the end of 4 hours exposure. All 3 larval stages appeared to be equally affected. In a saturated solution of lime, all animals died in 3 hours or less. The larvae of the first, or earliest stage, appeared to be the most resistant. Direct contact of lobster larvae with particles of lime resulted in the death of the animals. Again the animals of the first larval stage proved to be the most resistant, sometimes surviving as long as 40 minutes. Apparently the use of lime should be avoided during the time when lobster larvae are present in the water. Fortunately, the hatching of lobsters in Long Island Sound usually takes place in June, the time when the oystermen are preparing their beds for the new set of oysters, and lime will not be used at this time.

OBSERVATIONS ON OTHER FORMS

Barnacles were observed to live in a strong lime solution for periods of 6 months. They behaved normally and fed as if not disturbed. The local species of shrimp also withstood the lime treatment very well. On the other hand, crabs kept in tanks to which large quantities of lime were added soon died. No dead crabs were found, however, on the oyster beds treated with lime. Apparently, under natural conditions, crabs could always find small areas not covered with lime or could dig into the bottom mud, thus avoiding direct contact with lime. *Fundulus* were found to be very resistant. Flatfish, on the other hand, died within a few days after being placed in tanks with bottoms covered by a layer of lime. No dead flatfish were found on the natural beds where the concentration of lime was much lighter than in the experimental tanks, and where by flapping their fins, as is their habit, they could clean up a small area to rest on.

CONCLUSIONS AND RECOMMENDATIONS

Observations and experiments carried out by the writers under laboratory and field conditions indicate that the starfish living on oyster beds can either be eliminated entirely, or greatly reduced in numbers, by spreading common quicklime over the infested area.

The actual contact of the body of the starfish with the particles of lime is necessary to cause injury. Therefore, the efficiency of lime depends primarily upon its uniform distribution over the areas treated, and also upon the quantities used. The method of spreading lime over an area by shovels or by a stream of water should be discontinued as wasteful. Instead, methods insuring uniformity of distribution of the lime over the treated area should be employed. In all cases, the direction and speed of tidal currents should be taken into consideration. If properly applied, small quantities of lime (300 to 500 pounds per acre) will be sufficient to destroy the majority of the starfish present. Until more efficient methods of lime dispersal are developed, however, larger quantities, up to 1,000 pounds per acre, may be used. The cheapness of quicklime renders the method economically feasible. At the time of writing, the cost of 1 ton of quicklime delivered to oystermen ranged from $12 to $14. At this figure the cost of treatment per acre of bottom would vary from about $2 to $7, depending on the concentration used. At present, many oyster companies of Connecticut, New York, and Rhode Island are using lime regularly. Among these are Bluepoints Co., Inc., F. Mansfield & Sons Co., H. C. Rowe & Co., The Connecticut Oyster Farms, Inc., Warren Oyster Co., and Frank M. Flower & Sons.

It is fortunate that the concentrations of lime harmful to starfish do not seriously affect many other commercially important forms of marine life. When used in the concentrations employed in experiments, lime did not kill or noticeably injure oysters, clams, or other mollusks commonly found on cultivated bottoms. It was found injurious, however, to several pelagic forms, such as the larvae of flatfish and lobsters. By using lime at times when the larvae of commercially important species are absent, such injury can be avoided.

It is thought that lime can be advantageously used twice a year. The first treatment may be given in March, thereby killing starfish before the period of their spawning activities and thus reducing the numbers of their progeny, and the second in the fall or winter will protect the oyster set from being devoured by both young and adult starfish.

Frequent surveys of starfish distribution carried on during the ast 5 years indicate that certain areas of Long Island Sound are lways inhabited by very large numbers of starfish, consequently erving as centers of propagation and distribution of these pests. uch areas should be treated with lime, thus destroying large numers of starfish and preventing them from spreading to adjoining ottoms.

The simplicity of application of lime, its comparative harmlessess to oysters and many other commercial species, and the cheapess of the product, all indicate that the method provides a practical eapon against starfish.

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UNITED STATES DEPARTMENT OF THE INTERIOR

FISH AND WILDLIFE SERVICE

THE EFFECT OF HEAT AND MOISTURE ON THE FEEDING VALUE OF PILCHARD MEAL

RESEARCH REPORT 3

UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary

FISH AND WILDLIFE SERVICE
Ira N. Gabrielson, Director

Research Report 3

THE EFFECT OF HEAT AND MOISTURE ON THE FEEDING VALUE OF PILCHARD MEAL

By

WILLIAM B. LANHAM, Jr. and HUGO W. NILSON

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ABSTRACT

The fish meals produced today have in general proved to be excellent sources of protein for the balancing of farm-animal rations. Some potential users, however, have refrained from feeding these products because of reports implying that fish meals, when fed to farm animals and poultry, have caused symptoms of toxicity.

It was considered possible that the meals suspected of producing toxic symptoms may have been subjected to conditions after manufacture that had altered them in an unsatisfactory manner. Therefore, the effect of excessive heat and humidity to simulate extremely unsatisfactory storage conditions was studied with pilchard meal.

Pilchard meal was incorporated in otherwise purified diets containing as much as 25 percent of protein; of which more than 95 percent had been derived from pilchard meal. When these diets were fed to rats and chicks it was found that the excess heat and high humidity had not adversely altered the nutritive value of the meal. This indicates that fish meals can be used liberally in farm-animal rations as a source of minerals and superior protein, provided ordinary care is used to balance properly the ration for the other essential food elements.

THE EFFECT OF HEAT AND MOISTURE ON THE FEEDING VALUE OF PILCHARD MEAL

By WILLIAM B. LANHAM, JR., *Chemist*, and HUGO W. NILSON, *Pharmacologist*, *Division of Fishery Industries, Fish and Wildlife Service*

CONTENTS

	Page		Page
Introduction	1	Discussion	8
Feeding experiments	2	Conclusions	9
Rat-feeding experiment	3	Literature cited	9
Chick-feeding experiment	4		

INTRODUCTION

In the United States, fish meals have been recognized as a potential source of protein for farm-animal feeding only in comparatively recent years. The Norwegian Government, however, recommended their use as early as 1892, and succeeded in promoting widespread utilization in continental Europe. Although the use of fish meals in animal feeding had been advised as early as 1835 (Atwater 1877)[1], it was not until 1914–18 that high prices and actual scarcity of other feeds caused the farmers of America to utilize this previously neglected material in appreciable quantity.

In general, the fish meals produced today have proved to be excellent sources of protein for the balancing of farm-animal rations. Some potential users, however, have refrained from feeding these products because published reports have implied that cod-liver oil and fish meals have caused symptoms of toxicity when fed to animals and fowls.

Gautier and Morgues (1888) reported the presence of relatively large quantities of volatile aliphatic amines in fish meals, with isoamylamine, which they reported to be an active poison, composing about one-third of the total bases present. The other products found were hexylamine, dehydrolutidine, asellin, morrhuin, and morrhuic acid. These compounds produced paralysis, convulsions, and lack of growth. Hawk (1908) confirmed these findings. Similarly, Norris and Church (1930) observed a toxic action that was ascribed to certain nitrogenous bases when 2 percent of cod-liver oil was included in the diet of chicks. They found that 18 percent of dry yeast in the diet alleviated the toxicosis induced by feeding isoamylamine dissolved in oil at a level of 0.14–0.56 mg. of the amine per day. Gutteridge (1935) reported that the toxic action of sun-rendered cod-liver oil (0.31 percent nitrogen), when fed to poultry, was greatly lessened by deamination.

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[1] Publications referred to parenthetically by date are listed in the literature cited, p. 9.

Holst and Holbrook (1933) reported a "scurvey-like" disease i chicks fed a diet containing 20 percent of fish meal. Dam an Schöenheyder (1934) described a deficiency disease in chicks wit symptoms of leg paralysis, anemia, hemorrhage, and poor growth Halpin, Holmes, Elvehjem, and Hart (1935) stated that too muc fish meal in the diet produced crippled feet in chicks.

In many of these reports the symptoms described were similar—severe anemia with atypical blood cells, lesions on internal organ and muscles, both external and internal hemorrhages, paralysis stunted growth, and death. Birds less than 8 days old showe similar symptons when fed diets that did not affect older birds Cook and Scott (1935) stated that they could produce the diseas symptoms in birds fed an otherwise satisfactory diet by includin small quantities of nitrogenous bases, such as trimethylamine, diethylamine, and isoamylamine. These bases have been found in fish meals. Almquist (1936), however, was unable to confirm the experimental findings of Cook and Scott.

Many articles have been noted that report fish meals to be a satisfactory protein supplement in the rations of farm animals and fowls It is possible, therefore, that the meals suspected of producing toxic symptoms may have been subjected to conditions after manufacture that had altered them in an unsatisfactory manner. It has been suggested by some of the previously mentioned investigators that certain amines resulting from protein decomposition may have been responsible for the apparent toxicosis.

Owing to the desirability of making full use of fish meal as a protein supplement in the rations of farm animals and fowls, an investigation was conducted by the Fish and Wildlife Service to determine the factors affecting the feeding value of commercial pilchard meal. This meal served as practically the only source of protein in diets fed to rats and chicks. Part of the fish meal was partially decomposed under conditions of excess moisture and heat in order to determine whether toxic compounds were formed and whether this spoilage was of the type, but in a more severe degree, of that occurring in meal stored in unsatisfactory warehouses or in ship holds during transport. The problem was to determine whether the unfavorable effects reported in the literature were due to the presence of one or more toxic compounds in the meal, or were symptoms of a deficiency of one or more vitamins or minerals in the diet.

FEEDING EXPERIMENTS

A search of the literature did not reveal any experimental fish-meal diets for chicks, which had produced reasonably satisfactory growth, hat did not derive a considerable part of their protein from sources ther than fish meal. For this reason Pacific coast pilchard meal, n oily type, was selected, and a diet was formulated in which more han 95 percent of the protein was supplied by the meal.

Experimental diets.—Half of each meal sample was partially spoiled y first mixing it with water to a thick paste, and then heating it for week in large shallow metal trays at about 50° C. The meal thus reated developed an extremely foul odor. It was dried at a temperaure under 50° C., finely ground, and stored in covered metal cans.

TABLE 1.—*Approximate analyses of the fish-meal samples*

Sample	Percent by weight			
	Dry matter	Crude protein	Ether extract	Ash
ilchard, No. 1	92.75	68.20	3.09	13.73
ilchard, No. 2	90.57	65.50	4.35	11.88
poiled pilchard	91.16	57.80	3.92	20.36

Both bacterial decomposition and simple chemical hydrolyses took lace. A bacterial count of the spoiled meal showed more than a 0,000-fold increase in numbers over the commercial sample, with no ppreciable mold growth. The spoilage probably followed both ossible paths—formation of nitrogenous bases and liberation of mmonia. This partial decomposition was purposely permitted to ecome more extensive than would ordinarily occur, in order to ccentuate any alteration of the meal.

The commercial and experimentally spoiled meals were incorporated nto the following otherwise purified diets: For rats—fish meal to bring he total protein content to 20 percent by weight; sucrose, 20; lard, 2; cod-liver oil, 2; salt mixture, U. S. P. XI No. 2, 4; dried brewer's east, 2; wheat germ, 1; and dextrin to 100 parts by weight. This was supplemented by 0.12 mg. of thiamin hydrochloride and 1.2 mg. of crystalline riboflavin per kg. of diet. For chicks—fish meal, 35; dextrin, 36; sucrose, 15; lard, 5; salt mixture, 2; agar, 2; cod-liver oil, 2; dried brewer's yeast, 2; and wheat germ, 1 part by weight. The crystalline vitamin supplements were similar to those incorporated n the diet for rats.

RAT-FEEDING EXPERIMENT

The rats were allotted, at an initial live weight of 48 to 55 g., into 2 groups of 9 animals each. Diets containing commercial and experimentally spoiled pilchard meal were self-fed for a period of 60 days. The rats were housed individually in cages with screen floors, and twice weekly records of body weight and food consumption were taken. All animals were in excellent health at the close of the experimental period.

The small difference in food intake between groups can be corrected for in large measure by comparing the efficiency of the 2 diets on the basis of gain in weight per gram of protein intake (table 2). No statistically significant difference was found between these indices of efficiency for the 2 diets. Apparently the spoilage of the commercial pilchard meal under these conditions produced no detrimental effects on the nutritive value of the meal for rats.

TABLE 2.—*Data on gain in weight and food intake of rats after 60 days, when fed a diet containing about 30 percent pilchard meal*

Diet designation	Number of rats	Average gain in weight	Average food intake	Gain in weight per gram of protein intake and standard error
		Grams	*Grams*	*Grams*
Commercial pilchard	9	165	548	1.51±0.13
Spoiled pilchard	9	155	564	1.37±0.13

CHICK-FEEDING EXPERIMENT

Most of the unfavorable reports in the literature concerned poultry-feeding experiments, so a possibility existed that the lack of significant differences when feeding spoiled and unspoiled meal to rats may have been due, at least in part, to variations in species reaction. For this reason chicks were substituted for rats and the feeding experiments were repeated.

Day-old, cross-bred chicks were allotted into 2 comparable groups that received diets containing unspoiled and experimentally spoiled meal, respectively. The diets were self-fed after the third day, and the chicks were kept by groups in cages with screen floors. Group feed consumption and individual body weights were recorded at weekly intervals. After 4 weeks some of the birds began to develop a leg weakness that was believed to be perosis. This condition did not seem to alter the growth rate of most of the chicks, however, so the experiments were continued for a total of 7 weeks. Apparently no toxic compounds were produced by the spoilage conditions, since the average weight of the survivors of the group fed the treated meal was greater than that for the group fed the commercial meal (table 3).

In the second series of experiments the protein content of the diets was adjusted to 22 percent by weight, while in a third series 30 parts per million of manganese were added as $MnSO_4 \cdot H_2O$ to prevent perosis. The results of the second and third series of experiments were essentially the same as the first, since chicks fed the spoiled-meal diets did about as well as those fed commercial meal. An excessive mortality was experienced, but this condition cannot be ascribed to the fish meal because all the chicks died when fed a diet in which actalbumin was substituted for the fish meal (table 3). Some essential ingredient was deficient in these diets. It was soon found that the chicks fed the commercial meal were suffering from a deficiency of vitamin K, as evidenced by prolonged blood-clotting time, while chicks fed the spoiled-meal diets did not show this deficiency symptom.

Another series of experiments was conducted to determine whether a deficiency of vitamin K was responsible for the high mortality. One group of chicks received the commercial pilchard-meal diet in which 3 percent of lard was replaced by an equal weight of soybean oil as a source of vitamin K and the antiencephalomalacia factor. Another group received a different sample of pilchard meal. Fewer chicks died, but evidently the diet was still not properly balanced for all food essentials. The vitamin K deficiency was corrected by the addition of soybean oil, so 3 percent was included in all subsequent diets. Various supplements were added to the basal diet in an effort to reduce the mortality by supplying the deficient substances. Three percent additional yeast, 1 percent liver extract concentrate, 1 percent wheat-germ oil, 0.005 percent of nicotinic acid, or 5 percent of alfalfa leaf meal had no beneficial effect when incorporated singly in the commercial pilchard-meal diet.

Only 2 of 8 chicks fed the lactalbumin diet, and 2 of 10 fed the commercial pilchard-meal diet, died when the quantity of thiamin hydrochloride was tripled. None died in the group fed the spoiled pilchard-meal diet. For control purposes a group of 8 chicks was fed a chick mash made up as follows: Fish meal, 7.5; meat scrap, 7.5; dried skim milk powder, 5; alfalfa meal, 7.5; bone meal, 1; ground limestone, 2; salt, 1; cod-liver oil, 1; wheat bran, 16; ground yellow corn, 30; ground wheat, 10; and ground barley, 11.5 parts by weight (Almquist, Jukes, and Newlon, 1938). This mash gave better results than the commercial pilchard-meal diet, but did not produce as large birds as those receiving the spoiled pilchard-meal diet (table 4). These tests were repeated with about the same results.

Most of the chicks fed the diet containing spoiled pilchard meal attained a greater final weight at the end of a 6-week period than did chicks receiving the commercial pilchard-meal diet. Evidently some factor in addition to vitamin K was being synthesized by the spoilage process. There is reason to believe that this factor may be a member of the vitamin B complex, since the addition of 1 percent of a rice-bran extract concentrate to the commercial pilchard-meal diet produced marked improvement in results. Also, when 3 percent of rice-bran concentrate was added to the diet the chicks attained a weight greater than those fed either the spoiled-meal diet or the chick mash (table 4, experiment No. 5). Rice-bran extract concentrate is known to be an important source of several vitamins of the B complex.

TABLE 3.—*Final weight, food intake, and number of cases of perosis of chicks fed diets containing about 30 percent pilchard meal*

Diet designation	Number of chicks		Average weight of survivors	Coefficient of variability in weight	Average food intake of survivors [1]	Total number of cases of perosis	Gain in weight per gram of protein [2]
	Initial	Survivors					
EXPERIMENT No. 1 (7 weeks)							
			Grams	*Percent*	*Grams*		*Grams*
Commercial pilchard	9	1	210	----------	548	0	1.5
Spoiled pilchard	9	8	454	16.3	937	5	1.9
EXPERIMENT No. 2 [3] (6 weeks)							
Commercial pilchard	11	2	179	9.1	467	0	1.3
Spoiled pilchard	10	2	153	57.0	442	2	1.1
Commercial pilchard, plus manganese	8	0	----------	----------	----------	0	----------
Spoiled pilchard, plus manganese	8	6	301	30.1	664	0	1.7
Lactalbumin [4]	5	0	----------	----------	----------	0	----------
EXPERIMENT No. 3 [5] (6 weeks)							
Commercial pilchard, sample 1	8	0	----------	----------	----------	----------	----------
Commercial pilchard, plus soybean oil	7	4	223	20.8	519	----------	0.8
Commercial pilchard, sample 2	8	4	237	26.0	620	----------	1.0

[1] Data based on food intake per chick day.

[2] Data based on survivors.

[3] The protein content was adjusted to 22 percent by weight, and 30 parts per million of manganese were added to the diets.

[4] All dead at the end of 3 weeks.

[5] Diets contained 150 parts per million of added manganese.

TABLE 4.—*Final weight, food intake, and gain in weight per gram of protein of chicks fed mash and diets containing lactalbumin and pilchard meal*

EXPERIMENT No. 4 [1] (6 weeks)

Diet designation	Number of chicks		Average weight of survivors	Coefficient of variability in weight	Average food intake of survivors	Gain in weight per gram of protein
	Initial	Survivors				
			Grams	*Percent*	*Grams*	*Grams*
Commercial pilchard	10	8	346	35.7	707	2.3
Spoiled pilchard	10	10	547	18.5	1,034	2.4
Chicken mash	8	8	402	22.6	1,152	1.9
Commercial pilchard plus 1 percent of rice-bran concentrate	10	10	488	12.6	1,003	2.3

EXPERIMENT No. 5 [1] (6 weeks)

Diet designation	Initial	Survivors	Average weight of survivors	Coefficient of variability in weight	Average food intake of survivors	Gain in weight per gram of protein
Commercial pilchard	9	9	298	15.1	872	1.3
Spoiled pilchard	10	8	463	15.2	1,261	1.5
Chicken mash	9	9	412	14.0	1,462	1.4
Lactalbumin	8	6	152	26.2	451	1.2
Commercial pilchard plus 3 percent of rice-bran concentrate [2]	9	8	493	13.2	1,268	1.6

[1] Fish meal and lactalbumin diets were supplemented with 0.36 mg. of thiamin hydrochloride per kg. of diet.

[2] The revised diet consisted of pilchard meal, 31.4; dextrin, 35.6; sucrose, 15; wheat germ, 1; yeast, 2; agar, 2; salt mixture, 2; lard, 3; soybean oil, 3; cod-liver oil, 2; and rice-bran concentrate 3 parts by weight. It was supplemented with 0.36 mg. of crystalline thiamin hydrochloride, 1.2 mg. of riboflavin, and 100 parts per million of added manganese per kg. of diet.

DISCUSSION

The hemorrhagic symptoms reported by Dam and Schöenheyder as due to feeding fish meal have since been shown to be caused by a deficiency of vitamin K. Almquist and Stokstad (1936) found that chicks fed a vitamin K deficient diet containing 17.5 percent of ether-extracted fish meal showed hemorrhagic symptoms and a high death rate after a 3-week period. In the experiments herein reported, the introduction of a known source of vitamin K in the diets at sufficient levels to reduce the clotting time of the blood to normal values did not significantly reduce mortality.

The crippled feet in chicks reported by Halpin and coworkers (1935) to be the result of feeding diets containing a high percentage of fish meal may possibly have been a type of perosis accentuated by the high ash content of such diets. This conclusion was tentatively corroborated by the data from the first experimental series with chicks. No evidence of perosis was apparent, however, when the chicks were fed diets containing more than 30 percent pilchard meal supplemented with at least 30 parts per million of manganese.

The experimental data show no evidence that the type of spoilage used in these tests produced toxic compounds, and such spoilage did not reduce the nutritive value of the meal. The mortality was admittedly quite high in the first experiments with chicks, but normal death rates were experienced after the diet was properly supplemented with vitamins and manganese. The supplemented commercial pilchard-meal diet compared very favorably with the chick mash in producing larger birds at the end of a 6-week period. There was a comparatively large intake of fish meal from the diets, a fact that should have emphasized the acute symptoms of toxicosis if deleterious compounds were in the meal. The data indicate, however, that the experimental spoilage of pilchard meal produced no significant quantities of deleterious compounds. Spoilage apparently augmented the vitamin content, but deliberate spoilage is not recommended since the vitamin content of practical poultry rations can easily be balanced by the addition of such feeds as leafy legumes and a variety of cereals. The addition of manganese to the diets largely alleviated the deficiency that was responsible for the symptoms of perosis.

It would seem, therefore, that any toxicity ascribed to feeding commercially available fish meal probably was due to a deficiency state rather than a toxicosis produced by the action of one or more organic toxic compounds. This simply means that ordinary care must be taken to balance properly the vitamin and mineral content of the rations, making full use of fish meal as a source of a superior protein and some of the necessary minerals.

CONCLUSIONS

1. Experimental spoilage of commercial pilchard meal by heat and moisture does not adversely alter the nutritive value of the protein.

2. Experimental spoilage of the meal greatly increased the vitamin K content.

3. Chicks fed an otherwise purified diet containing 31 percent of pilchard meal were successfully raised to the age of 6 weeks, after which the experiments had to be terminated owing to lack of equipment. This diet compared favorably with a standardized chick mash in producing healthy birds.

4. Pilchard meal is recommended for liberal use in farm-animal rations as a source of superior protein and some necessary minerals, provided ordinary care is used to balance the rations for other essential food elements.

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METABOLISM STUDIES WITH ALGIN AND GELATIN

RESEARCH REPORT No. 4

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Ira N. Gabrielson, Director

Research Report No. 4

METABOLISM STUDIES WITH ALGIN AND GELATIN

By

HUGO W. NILSON and J. M. LEMON

UNITED STATES
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ABSTRACT

ALGIN, a salt of alginic acid extracted from kelp, and gelatin, produced from animal bones and skins, are used as stabilizing agents in the manufacture of ice cream and in certain other food products. Studies were conducted with growing male rats over a period of 10 weeks to determine the nutritive effects of the vegetable gum of algin and the protein of gelatin.

The apparent digestibility of algin varied directly with the level fed. Algin was utilized efficiently after absorption. Gelatin was highly digested irrespective of the level fed, but more food was required per unit increase in live weight. No characteristic symptoms were noted that could be attributed to acute or chronic toxicity. Both algin and gelatin were found to be wholesome foods.

METABOLISM STUDIES WITH ALGIN AND GELATIN

By Hugo W. Nilson, *Pharmacologist,* and J. M. Lemon, *Technologist, Division of Fishery Industries, Fish and Wildlife Service*

CONTENTS

	Page		Page
Introduction	1	Discussion	8
Experimental data	1	Summary	8
Animal-feeding experiments	3	Literature cited	9

INTRODUCTION

Algin, a salt of alginic acid extracted from kelp, and gelatin, produced from animal bones and skins, have been used for some time as stabilizing agents in the manufacture of ice cream and in similar food products. In ice cream they function through certain of their colloidal properties by affecting the size and nature of ice-crystal formation during the freezing and hardening process and storage; thereby producing a smoother product. Algin also is used to a considerable extent in stabilizing chocolate milk. Members of industries utilizing marine plants are particularly interested in determining some of the metabolic constants of these products.

This investigation was begun in March 1939 in the technological laboratories of the Fish and Wildlife Service. The algin and two grades of gelatin used were purchased from ice cream manufacturers. One grade was a bone gelatin of high gel strength, while the other was manufactured from skins. Gelatin manufactured from skins is used to a greater extent as a stabilizer in ice cream.

EXPERIMENTAL DATA

The algin tested was a sodium alginate product extracted from *Macrocystis pyrifera,* the giant kelp that grows off the coast of California. The product was standardized to uniform colloidal strength with sugar and dextrin and treated with phosphate to make it soluble in milk. Goodman (1935)[1] reported that about 0.15 to 0.25 percent of sodium alginate produced satisfactory stabilization of ice cream. Sommer (1938) pp. 428–433, found that 0.25 percent of sodium alginate was equal or slightly superior to 0.4 percent 225 Bloom gelatin for this purpose. Anderson, Dowd, and Helmboldt (1937) reported an improvement in the sodium alginate mix over a gelatin mix, and that algin

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[1] Publications referred to parenthetically by date are listed in the literature cited, p. 9.

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as a stabilizer produced an ice cream with a smoother and creamier melt down.

Chemically, sodium alginate consists of the sodium salt of polymerized d-mannuronic acid in which the carboxyl groups are free and all of the aldehyde groups are shielded by linkages. About 71 percent of algin with sugar and dextrin may be classed as carbohydrate, and it was incorporated into diets in replacement of part of the sugar and dextrin (tables 1 and 2).

TABLE 1.—*Composition of diets used*

Ingredients	Percent by weight								
	Diet No. 1 (control)	Diet No. 2	Diet No. 3	Diet No. 4	Diet No. 5	Diet No. 6	Diet No. 7	Diet No. 8	Diet No. 9
Algin		5.0	10.0	20.0	30.0				
Gelatin						5.0	10.0	20.0	30.0
Sucrose	27.0	25.1	23.4	19.1	15.8	26.0	25.0	23.0	20.4
Dextrin, tapioca	25.0	23.1	21.5	17.7	14.4	23.6	23.2	20.8	19.0
Lard	15.0	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Casein, technical	15.0								
Lactalbumin, technical	5.0								
Brewer's yeast, dried	5.0								
Wheat germ	2.0								
Cod liver oil	2.0								
Salt mixture, regular	4.0					4.0	4.0	4.0	4.0
Salt mixture, No. 1		3.3	.5						
Salt mixture, No. 2			2.0	2.0					
Supplement value:									
Protein equivalent						2.0	5.0	10.0	15.0
Carbohydrate equivalent		3.8	7.1	15.2	21.8	2.4	3.8	8.2	12.6
Mineral equivalent		.5	1.5	2.0	3.0				
Excess moisture		.7	1.4	2.8	4.2	.6	1.2	1.8	2.4

[1] Same in all diets.

TABLE 2.—*The composition of the algin, gelatin, and the salt mixtures used*

Ingredients	Percent by weight					
	Algin with sugar and dextrin	Gelatin		Salt mixture		
		Skin	Bone	Regular	No. 1	No. 2
Moisture	14.0	12.0	12.0			
Mannuronic units	37.0					
Gelatin		86.8	87.8			
Ash	15.0	1.6	.2			
Sucrose	17.0					
Dextrin	17.0					
Calcium lactate				31.0	55.0	65.0
Dicalcium phosphate				11.0		
Dipotassium phosphate				22.0		
Potassium chloride				12.5	15.0	18.0
Sodium chloride				8.0		
Calcium carbonate				7.0	15.0	
Magnesium carbonate				3.0	8.0	8.0
Magnesium sulfate				3.7	1.5	
Ferric citrate				1.3	4.0	6.5
Copper sulfate				.4	1.0	1.5
Manganese sulfate				.1	.5	1.0
Potassium iodide				.01	.01	0.2

Gelatin, a byproduct of the meat-packing industry, is a protein derived from white fibers contained in pig and calf skins, and ossein obtained from bones. Two grades were used in the experimental studies. Since gelatin is a protein, it was incorporated into the experimental diets in partial replacement of the casein and lactalbumin which supplied the protein of the basal diet. Gelatin is an incomplete protein, so enough casein and lactalbumin was included in all diets to at least approximately balance the gelatin protein. In no instance did a diet contain more than 35 percent protein. This higher level of protein has been found satisfactory for normal growth of rats in experiments in which casein was fed (Morris, Palmer, and Kennedy 1933).

ANIMAL-FEEDING EXPERIMENTS

Male albino rats, 4 weeks old, were allotted into nine groups of six animals each, with an average initial live weight per group of 53 to 54 g. The maximum range in individual live weight was 48 to 58 g. The animals were individually housed in screen cages that were fitted with screen floors. Food and water were fed freely and the intake of each animal was recorded. The food intake of the various groups was calculated to the equivalent dry-matter content of the control diet, and the excess was added to the water-intake records.

Groups were allotted to be fed the control diet and diets containing approximately 5, 10, 20, and 30 percent algin with sugar and dextrin, and 5, 10, 20, and 30 percent gelatin (tables 1 and 2). Three rats of each gelatin-fed group received bone gelatin, while the other three received skin gelatin. The data show no significant differences in response, so the results from the subgroups were summarized together in the final computation. The quantities of algin or gelatin fed were chosen arbitrarily, but the smaller amount represents about 20 times the quantity usually incorporated in ice cream.

Only one 9-week test was originally contemplated. In order to obtain accurate apparent digestibility coefficients representing the entire period, paper towels were spread under the screen floors and the feces collected every 2 or 3 days. Feces samples from individual rats were kept in a cool place and later dried to determine the dry-matter content. Preliminary tests soon showed that the algin could not be readily extracted from the dried feces. Consequently another sample was collected during the tenth week for the determination of algin, total nitrogen, and dry-matter content. Data for gain in weight, and food and water requirements cover the 10-week period, while data on the apparent digestibility of algin and the total protein are limited to the tenth week.

The algin content of the feces collected during the tenth week was determined for individual rats by digesting a 3-g. sample with 10 ml. of

0.5N/NaOH and 20 ml. water. The suspension was filtered after the addition of 10 ml. of saturated $(NH_4)_2SO_4$ and the undigested matter was washed with an additional 10 ml. of $(NH_4)_2SO_4$. Twenty-five ml. of a 40 percent solution of $CaCl_2$ and 25 ml. of water were added to the filtrate to precipitate the algin. Filter aid was added and the suspension was filtered through a Buchner filter. The filter cake was washed thoroughly with a saturated $(NH_4)_2SO_4$ solution. The amount of algin was calculated from the difference in weight after drying and then igniting the filter cake. Some difficulty was experienced with occlusion of protein. This procedure probably does not give an absolutely true answer, but it was considered to be the best approximation that could be obtained under the circumstances. The total crude protein content was determined by the modified Kjeldahl method of the A.O.A.C. on samples of feces collected during the tenth week from individual rats fed the control and gelatin diets.

In general, the rats grew very well and at the close of the 10-week period the mean live weight per rat ranged from 332 g. for the group fed the control diet to 123 g. for the group fed the diet containing 30 percent gelatin. The comparative mean live weights were 314, 312, 243, and 208 g. for the algin-fed rats, and 286, 241, 209 and 123 g. for the gelatin-fed rats for the 5, 10, 20, and 30 percent levels, respectively.

Two rats died in each of the groups that were fed algin. These rats sickened and died from 9 to 17 days after being fed the experimental diet. Since these animals died within such a short period, it was considered probable that the bacterial flora of the intestinal tract may have been an important factor. The rats that died may not have become properly infected with a type of bacteria that could grow satisfactorily in the algin media. The problem of physical impaction did not appear to be a factor even with rats fed the high levels of algin.

In order to test the significance of this interpretation, certain rats which had been fed similar diets containing 20 and 30 percent agar during the 10-week period were fed a diet containing 20 percent algin. They were killed at about 4-day intervals and 1-g. samples of the contents of the small intestine and cecum were diluted and plated on nutrient agar.

The data in table 3 show that there was a marked decrease in the bacterial numbers about the twelfth day. The rats that lived through this period showed a subsequent higher bacterial count of the intestinal contents, while those that died showed evidence that the food was not properly digested. Complete differential studies were not made, but it appeared that the grayish-blue colonies were gram negative rods and the small brownish colonies were gram positive cocci. The data are very incomplete, but apparently the bacterial flora of the intestinal tract was an important factor in the efficient utilization of food and in the health of the animals.

No characteristic lesions were found during necropsy of the rats that died when fed the regular experimental diet. The mean total fecal excretion of dry matter per rat during the 10-week period was 26 g. for the control group; 35, 38, 33, and 29 g. for the groups fed algin; and 19, 24, 16, and 12 g. for the groups fed gelatin at the 5, 10, 20, and 30 percent levels. The dry-matter content of the feces varied from 57 to 78 percent.

The data in table 4 show that the rats of all groups except those fed the 30 percent level of gelatin grew rather uniformly, although, only the rats fed the 5 and 10 percent levels of algin grew as well as the control group.

TABLE 3.—*A study of the bacterial flora in the contents of the intestinal tracts of rats fed a diet that contained 20 percent agar prior to June 7*

Rat number and diet fed	Date	Bacterial count in millions per gram		Remarks
		Small intestine	Cecum	
20 percent agar:				
121	June 23	3.3	10	The intestines were fairly well filled with food. The cecum was small and compact. Grayish-blue colonies.
117	July 5	1.5	9	Do.
20 percent algin:				
125	June 11	2.1	628	All grayish-blue colonies.
124	June 15	4.4	21	About 3 times as much food in intestines as for rat No. 125. Grayish-blue and brown colonies.
123	June 19	.2	3	The intestines contained very little food, but the cecum contained considerable solid food. Grayish-blue and brown colonies.
118	June 23	3.0	14	The intestines were filled with what appeared to be algin. The cecum was quite large and well filled with a greenish material. Grayish-blue and brown colonies.
120	do			Killed because he was obviously sick. He did not have any food in the cecum or intestines.
126	June 26			Died No food was found in the cecum or intestines.
122	June 27	16.0	14	The intestines were filled with an algin-like substance. Grayish-blue, brown, and a few white colonies.

TABLE 4.—*Daily gain in weight of rats for the 10-week period*

Group designation	Number of survivors	Mean daily gain	Coefficient of variation	Mean difference from control	Percent level of *t*
		Grams	*Percent*	*Grams*	
Control	6	3.99	13		
Algin:					
5 percent	4	3.72	20	0.27	[1]
10 percent	4	3.53	9	.46	[1]
20 percent	4	2.98	9	1.01	4
30 percent	4	2.20	21	1.79	1
Gelatin:					
5 percent	6	3.31	5	.68	5
10 percent	6	3.10	11	.89	2
20 percent	6	2.22	10	1.77	<1
30 percent	6	.99	31	3.00	<1

[1] Nonsignificant difference.

The data in table 5 are interesting since they show that none of the rats fed algin required more food per gram gain in weight than the control rats. The greater variability of food requirement for the rats fed 30 percent algin (coefficient of variation equals 17 percent), and the smaller number of animals, made the difference from control of 0.85 g. insignificant. This finding need not be emphasized, since what happens when the lower levels are fed is of greater importance from the standpoint of stabilizers in foods. The groups fed gelatin all required more food per gram gain than did the control rats. There was no effect of increasing levels on the apparent digestibility of the dry matter of the diet, and the diets were digested surprisingly well in all instances.

The water requirement per gram gain in weight varies as may be expected (table 6). It is interesting to note that the rats fed the 5 and 10 percent levels of both algin and gelatin required about the same amount of water per gram gain in weight as the control group. Those fed the greater levels of either material showed a higher requirement which may be explained, at least in part, by the decreased growth rate. The mean, free-choice water consumption for the 10-week period was roughly 1,400 g. for the control group; 1,525, 1,450, 1,750, and 2,000 g. for the algin-fed rats; and 1,300, 1,275, 1,300, and 950 g. for the gelatin-fed rats.

TABLE 5.—*Food required per gram gain in weight and the apparent digestibility of dry matter for the 10-week period*

Group designation	Mean food required	Coefficient of variation	Mean difference from control	Percent level of *t*	Mean apparent digestibility of dry matter
	Grams	*Percent*	*Grams*		*Percent*
Control	3.00	6			96.6
Algin:					
5 percent	3.30	11	0.30	(1)	94.6
10 percent	3.22	8	.22	(1)	94.8
20 percent	3.34	8	.34	(1)	94.8
30 percent	3.85	17	.85	(1)	94.4
Gelatin:					
5 percent	3.31	4	.31	3	97.2
10 percent	3.54	9	.54	2	96.5
20 percent	4.17	16	1.17	1	97.1
30 percent	6.71	17	3.71	<1	97.0

[1] Non-significant difference.

TABLE 6.—*Water required per gram gain in weight for the 10-week period*

Group designation	Mean water required	Coefficient of variation	Mean difference from control	Percent level of *t*
	Grams	*Percent*	*Grams*	
Control	4.91	18		
Algin:				
5 percent	6.22	26	1.31	(1)
10 percent	5.94	8	1.03	(1)
20 percent	8.64	25	3.73	5
30 percent	13.24	8	8.33	<1
Gelatin:				
5 percent	5.67	17	.76	(1)
10 percent	5.98	9	1.07	(1)
20 percent	8.29	10	3.38	<1
30 percent	14.33	21	9.42	<1

[1] Nonsignificant difference.

The tenth week served as a feces-collection period in order to determine the digestibility of the algin and the total crude protein of the control diet and those containing gelatin. Some variation in apparent digestibility may be due to the fact that the food-intake data were taken from the period in which the feces were collected, and day-to-day fluctuations in food intake and feces excretion would have a greater effect during a period of 1 week than for a longer period. This factor may be responsible for part of the rather large coefficients of variation of 79 and 27 percent for the groups fed 5 and 10 percent algin diets (table 7).

The data in table 7 show an increasing apparent digestibility of the algin with increasing level in the diet. There was a statistically significant difference in every case. Either there was an adaptation of the intestinal tract to use a greater amount of the algin in the higher levels in order to conserve food supply, or the micro-organisms responsible for digestion grew better in the intestinal contents containing the higher levels of algin. The algin after digestion was apparently well utilized by the animal, since the data in table 5 show no significantly greater amount of food required per gram gain in weight as the algin content of the diet increased from 0 to 30 percent. Apparently the algin has considerable nutritive value and can be efficiently utilized when properly digested.

TABLE 7.—*Apparent digestibility of algin for a 1-week period*

Group designation	Mean apparent digestibility	Coefficient of variation	Mean difference within series	Percent level of *t*
Algin:	*Percent*	*Percent*	*Percent*	
5 percent	3.0	79		
10 percent	35.9	27	32.9	<1
20 percent	63.4	7	60.4	<1
30 percent	88.3	3	85.3	<1
10 percent				
20 percent			27.5	2
30 percent			52.4	<1
20 percent				
30 percent			24.9	<1

The data in table 8 show a very uniform apparent digestibility of the total protein of the control diet and the diets containing increasing levels of gelatin. The coefficients of variation were very small, indicating a high degree of uniformity. Apparently the gelatin was very digestible irrespective of the level fed, but the data in table 5 indicate a significantly higher quantity of food required per gram gain in weight when the gelatin was added to the diet and when the level of gelatin in the diet was increased.

TABLE 8.—*Apparent digestibility of the total protein of the diet for a 1-week period*

Group designation	Mean apparent digestibility	Coefficient of variation	Mean difference	Percent level of *t*
	Percent	*Percent*	*Percent*	
Control	89.2	1.4		
Gelatin:				
5 percent	88.5	1.8	0.7	(1)
10 percent	87.5	1.6	1.7	(1)
20 percent	89.8	1.4	.6	(1)
30 percent	92.1	1.3	2.9	(1)

[1] Nonsignificant difference.

DISCUSSION

These studies are concerned only with the nutritive values of the vegetable gum of algin and the protein of gelatin. In the final analysis, however, both products are used only in very small amounts as stabilizers in food products, because of their physical effects upon them. Although the nutritive values of the products are of secondary importance, both are wholesome. Two rats in each algin-fed group died soon after being fed the diets, but only negative lesions were found on necropsy. The survivors made reasonably satisfactory gains in weight. The gelatin-fed rats grew at a significantly lower rate than the control rats and required more food per gram gain in weight, but all lived. The group fed the control diet, and the combined groups which had previously been fed the 5 and 10 percent levels of algin or gelatin were fed the 5 percent levels of algin and gelatin and these groups have been continued on experiment for over 2 years. Deaths were finally due to pneumonia and malignant tumors, except 1 rat fed algin died of coronary embolism and another of possible digestive disturbance or intestinal infection.

SUMMARY

Male albino rats with an average initial live weight of 53 to 54 g. were fed individually for one 10-week period on a control diet supplemented with 5, 10, 20, and 30 percent of algin with sugar and dextrin, and 5, 10, 20, and 30 percent of gelatin. The apparent digestibility of the algin ranged from 3 to 88 percent, depending upon the level fed. The apparent digestibility of the total protein of the diets containing gelatin varied from about 88 to 92 percent. Both algin and gelatin were found to be wholesome foods.

Ten male rats of similar initial weight, but from another colony, were later fed the basal diet (salt replaced the salt mixture) plus 10 percent of algin with sugar and dextrin. None of the rats died during the 10-week period. The average daily gain was 3.20 g., and 3.32 g. of food and 8.04 g. of water were required for each gram gain in weight.

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UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

THE WHITE-NECKED RAVEN IN RELATION TO AGRICULTURE

RESEARCH REPORT 5

UNITED STATES DEPARTMENT OF THE INTERIOR
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Research Report 5

THE WHITE-NECKED RAVEN IN RELATION TO AGRICULTURE

BY

SHALER E. ALDOUS

UNITED STATES
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ABSTRACT

THE WHITE-NECKED RAVEN (*Corvus cryptoleucus*), a close relative of the common crow, is indigenous to southwestern United States and the adjoining sections of Mexico. Because in parts of its range it has gained the same ill repute as acquired by the crow and magpie in their respective ranges, a 5-year detailed study of its activities and food habits was made, during which many field data were gathered, and the contents of 827 stomachs were analyzed.

The omnivorous food habits of this raven often bring it into direct competition with farming interests, and frequently its depredations result in severe damage to crops, particularly to grain sorghums, corn, melons, peanuts, pecans, weak lambs, and poultry. To reduce these attacks and keep the losses at a minimum often is expensive and requires considerable work and ingenuity on the part of farmers and ranchers. On the other hand nearly half the raven's food is of animal origin and includes a wide assortment of insects, many of which are harmful to crops. Grasshoppers, weevils, May beetles, caterpillars, fly maggots, and like pests constitute a material part of the insect diet. Carrion is another important food of the raven, and its removal from the range is a definite aid to sanitation.

When heavy raven concentrations occur, the crops must be protected. As effective control is impossible when natural food is abundant, it is generally necessary to resort to frightening measures until winter sets in and the food supply becomes low enough to insure control success. Various contrivances to scare the birds away may be placed in the fields, but the shotgun is without question the best frightening device. The most successful, selective, and humane control measure is the use of large cage traps (illustrated in fig. 12 in this report). As the need for control is usually local and varies by seasons, depending upon the crop situation, the soundest policy is to resort to it only when necessary and to take advantage of the bird's better attributes at all other times.

THE WHITE-NECKED RAVEN IN RELATION TO AGRICULTURE

By Shaler E. Aldous

Biologist, Division of Wildlife Research, Fish and Wildlife Service [1]

CONTENTS

	Page
Reason for the study	1
Description	2
Distribution	4
Life history notes	6
Breeding habits	6
Mating	6
Nesting	7
Eggs	7
Nestlings	9
Behavior at the nest	9
Roosting habits	10
Movements	13
Molting	15
Parasites	15
Damage caused by ravens	16
Crop losses	16
Farm-to-farm canvass	16
Dissemination of diseases	17
Interference with telephone service	17
Food habits	18
Number and distribution of stomachs	18
Food of adults	18
Animal food	22
Plant food	32
Miscellaneous items	40
Food of nestlings	40
Animal food	42
Plant food	44
Summary of food habits	44
Items identified in the stomachs	47
Economic status	51
Crop protection	52
Frightening devices	52
Control measures	53
Trapping	53
Destroying nests, eggs, and young	54
Poisoning	54
Explosives	55
Literature cited	55

REASON FOR THE STUDY

Because of the increasing number of complaints against the white-necked raven (*Corvus cryptoleucus*) in Texas, in October 1931 the Biological Survey [2] initiated a detailed study of the bird's activities and during the following 5 years gathered information on the bird's habits. The field data obtained, supported by the findings from the laboratory analyses of 827 stomachs, constitute the basis for this report.

Inasmuch as the white-necked raven has little esthetic appeal, its economic rating depends almost wholly on its food habits. Its status is a controversial subject, but the species generally is considered wholly detrimental by the average farmer and sportsman. In western Texas, eastern and southern New Mexico, and southern Arizona it occupies the same position of disrepute as the crow in the East and Middle West and the magpie in the Rocky Mountain region. The omnivorous food habits and gregariousness of these three members of the family Corvidae combined with their ability to adjust themselves to changing environments make them recurring problems in their respective ranges. The crow and the magpie have been dealt with exhaustively in publications by Kalmbach (1918, 1927),[3] but no comprehensive treatise on the white-necked raven has been issued.

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[1] Report prepared while the author was employed in what is now the Section of Food Habits.

[2] On June 30, 1940, the Bureau of Biological Survey was consolidated with the Bureau of Fisheries to form the Fish and Wildlife Service.

DESCRIPTION

The common name "white-necked raven" is somewhat misleading, because to the uninitiated it signifies a bird with a white neck. The term is adapted, however, from the scientific name *Corvus cryptoleucus*, which means the raven with the hidden white. Although the basal two-thirds of all the feathers of the neck and anterior parts of the breast and back are pure white, the tips of these feathers and the whole of the remaining body covering are black, so that in outward appearance the bird is wholly black (fig. 1).

The original description of the species by Couch (1854: 66) is as follows:

> FEMALE. *Form.*—Bill short, high at base, compressed; nostrils covered with flat, bristle-like feathers, which are about two-thirds as long as the bill. Wings long, fourth primary longest, first short; tail moderate, rounded. About the size of or rather larger than the common crow of North America, (*Corvus americanus*).
>
> *Color.* Entirely black, with violet and purple reflexions. Feathers of the neck before and behind, and of the back, pure white at their bases and for about two-thirds of their length, being, in fact, white tipped with black. Bill and feet black. Iris yellowish brown.
>
> Total length from tip of bill to end of tail 18¾; wing 13½; expanse of wings 33; tail 8 inches.
>
> *Locality.* State of Tamaulipas, Mexico; March, 1853.

The extreme and average measurements of 108 adult white-necked ravens measured by the writer are shown in table 1, from which it may be seen that the type specimen is somewhat smaller than the average of the 56 females measured. Measurements were made in accordance with the technique set forth by Baldwin, Oberholser, and Worley (1931) except that the tail was measured from the base of the uropygium to the tip of the longest tail feather.

TABLE 1.—*Measurements taken in the flesh of 108 adult white-necked ravens*

Sex	Total length		Extent of wings		Wing		Tail	
	Mm.	*In.*	*Mm.*	*In.*	*Mm.*	*In.*	*Mm.*	*In.*
Males (52):								
Largest	533	21.00	1,124	44.25	375	14.75	229	9.00
Smallest	464	18.25	1,010	39.75	337	13.25	203	8.00
Average	506	19.91	1,063	41.83	359	14.14	215	8.45
Females (56):								
Largest	521	20.50	1,067	42.00	356	14.00	216	8.50
Smallest	457	18.00	927	36.50	349	13.75	184	7.25
Average	491	19.35	1,030	40.55	347	13.65	208	8.19

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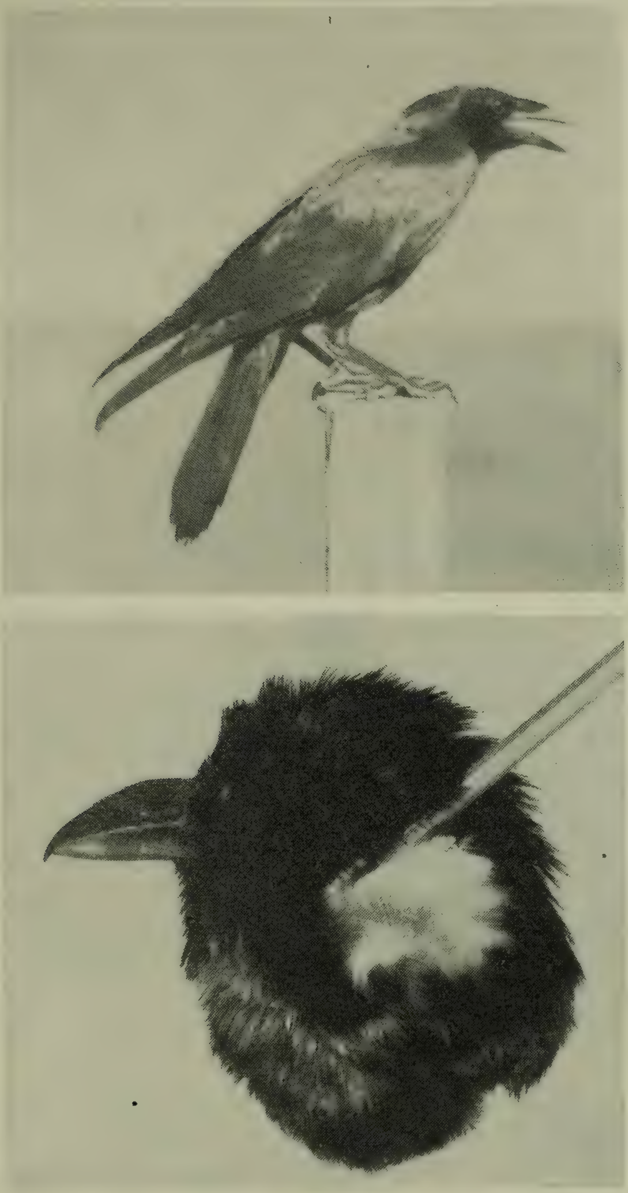
[3] Publications referred to parenthetically by date (alone or with colon and specific page) are listed in the Literature Cited, p. 55.



B37980; B49624

IGURE 1.—The white-necked raven (*Corvus cryptoleucus*). The bird receives its name from the pure white basal part of the neck feathers.

The weights of 67 female and 75 male white-necked ravens were recorded. They averaged 509 grams (17.9 oz.) for the females and 557 grams (19.6 oz.) for the males. The heaviest female weighed 607 and the lightest 407 grams. Extremes for the males were 667 and 464 grams. As all weights were taken during late fall and in winter and spring, the lighter ones do not indicate immature birds.

The statement made in the original description that this raven is slightly larger than the crow is confirmed by the data in table 2, which presents for comparison the average weights and measurements of white-necked ravens given in the preceding paragraph and in table 1 and those the writer obtained of 301 crows in Oklahoma (unpublished).

TABLE 2.—*Average weights and measurements of white-necked ravens* (Corvus cryptoleucus) *and crows* (C. brachyrhynchos)

Sex and bird	Weight	Measurements			
		Total length	Extent of wings	Wing	Tail
	Gm.	*Mm.*	*Mm.*	*Mm.*	*Mm.*
Males:					
White-necked ravens	557	506	1,063	359	215
Crows	500	477	937	318	195
Females:					
White-necked ravens	509	491	1,030	347	208
Crows	443	457	904	307	187

The field character that best distinguishes the white-necked raven from the crow, with which it intermingles on the north and east boundaries of its range in Texas and Oklahoma, is without question the raven's less open-throated and distinctly lower-pitched and guttural voice. Other distinguishing field characteristics are the raven's slightly larger size; its longer and coarser beak; its slightly more rounded tail silhouette when in flight; and its tendency to soar, at which time the tips of the primaries are separated and upturned. Occasionally, also, the white bases of its neck feathers can be seen when the plumage is ruffled by the wind (fig. 1).

DISTRIBUTION

Early distribution records indicate a much wider former range fo the white-necked raven than is known at present. Aiken (1873 stated that the bird was common along the base of the Rocky Mountains from Trinidad, Colo., to Cheyenne, Wyo., and from the Snow Range to a point 30 miles out on the plain. His is the only recor ever published for Wyoming. Birds of this species were reporte present around Boulder, Colo., in December 1921 by Beard (1922 and in the vicinity of Denver in 1932 by W. H. Bergtold (letter) J. A. Loring (field notes) recorded them as common in December 189 t La Plata, N. Mex., and E. W. Nelson (field notes) reported them a ew miles north at Durango, Colo., in April 1914. The species ight, therefore, be expected to follow along the San Juan River nto Utah, but no records are known for that State.

The most westerly record (Grinnell 1898: 32) is for the San 'ernando Valley, Calif. It is based on the partly decomposed emains of a raven found under a tree by F. S. Daggett on April 8, 1897, undoubtedly a stray bird, as no other specimens have been eported from the State. There are dubious records for the vicinity f Yuma, Ariz., but no authentic ones, although it seems reasonable hat the birds should occur there. Monson (1936) reported them ommon on the Papago Indian Reservation, west of Tucson, Ariz.

The most easterly record is for Galveston, Tex. (Bendire 1895: 3), where several of the birds were seen in May 1890. This is mewhat east of the usual range of the bird, as the normal eastern rder is the coastal region near the mouth of the Nueces River and ishop, Tex.

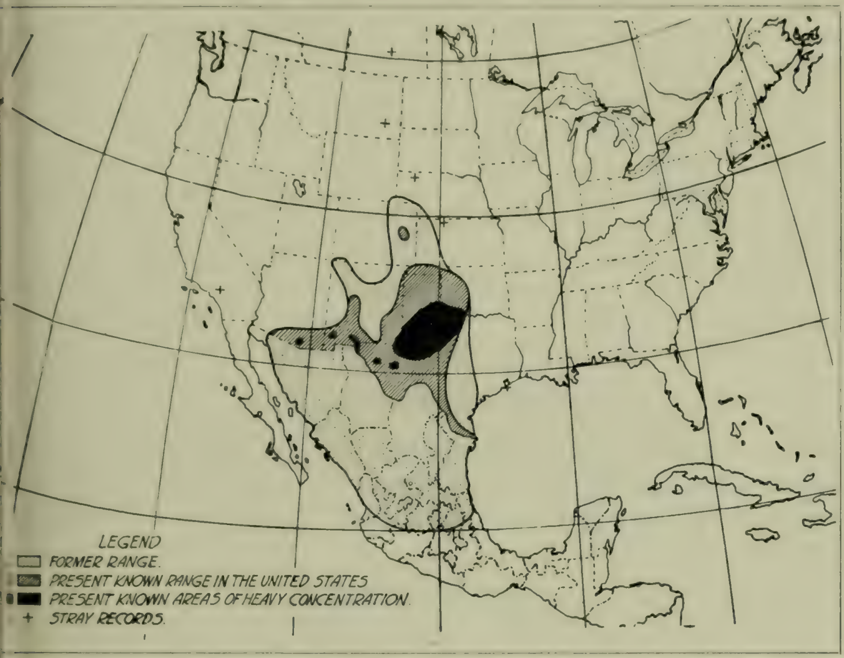

LEGEND
▭ FORMER RANGE.
▨ PRESENT KNOWN RANGE IN THE UNITED STATES
■ PRESENT KNOWN AREAS OF HEAVY CONCENTRATION.
+ STRAY RECORDS.
B8354M

FIGURE 2.—Range of the white-necked raven.

There are two records from Nebraska in the nineties (Bruner 1896: 2), probably stragglers, as in more than 40 years the birds have ot again been reported in that State. Several of the birds were corded in western Kansas in the late 1800's; and it seems reasonable assume their presence there now in limited numbers, as the species is known to occur in eastern Colorado. F. W. Robl (letter) wrote of a specimen shot at Ellinwood, Kans., November 8, 1934, but this is undoubtedly east of the bird's normal range. A number of early and recent records for Panhandle and western Oklahoma establish the species as a regular inhabitant of that State. Two sight records far north of the normal range include a bird reported near Fallon, Custer [=Prairie] County, Mont., in 1902 (Cameron 1907: 393) and one seen some years ago by Mrs. C. W. Cates (letter 1932) with some crows at "Bonnie brae" McLean, Saskatchewan, Canada.

At present the greatest concentrations of white-necked ravens in the United States occur in southeastern Arizona, southern and eastern New Mexico, and western Texas from about Wichita Falls south to the southern tip of the State and south of a line between Wichita Falls and Lubbock. The distribution map given as figure 2 epitomizes the records listed in the literature and the numerous observations made by the writer. Most of the material for this report was gathered from the areas in black.

Data on the distribution of the species in Mexico are rather meager and are confined mostly to reports previous to 1900 that established the northern Mexican range by records along the border in the southern parts of Arizona, New Mexico, and Texas, fairly well defined the southern and eastern boundaries of the range, but contained no records for western Mexico below the border, making the boundary line there somewhat hypothetical. The Mexican distribution as shown in figure 2 is therefore only an approximation.

LIFE HISTORY NOTES

The more outstanding traits and habits of the white-necked raven are discussed briefly in the following paragraphs, as many of them are useful in appraising the bird's economic status and in developing control measures.

BREEDING HABITS

MATING

In western Texas white-necked ravens begin pairing off early in March and at least 75 percent of them are mated by the middle of May. E. R. Kalbach reported (letter) a few birds in eastern Colorado pairing as early as January. Soon after mating takes place the testes, which previous to sexual maturity are about the size of wheat kernels, start enlarging, and they make enormous growth during the breeding season. One set had enlarged to 5 by 10 mm when measured on March 27, 1936, and another pair measured 16 by 25 mm. on May 4. The parent birds remain together until the young leave the nest, after which it is difficult to keep track of individual birds.

NESTING

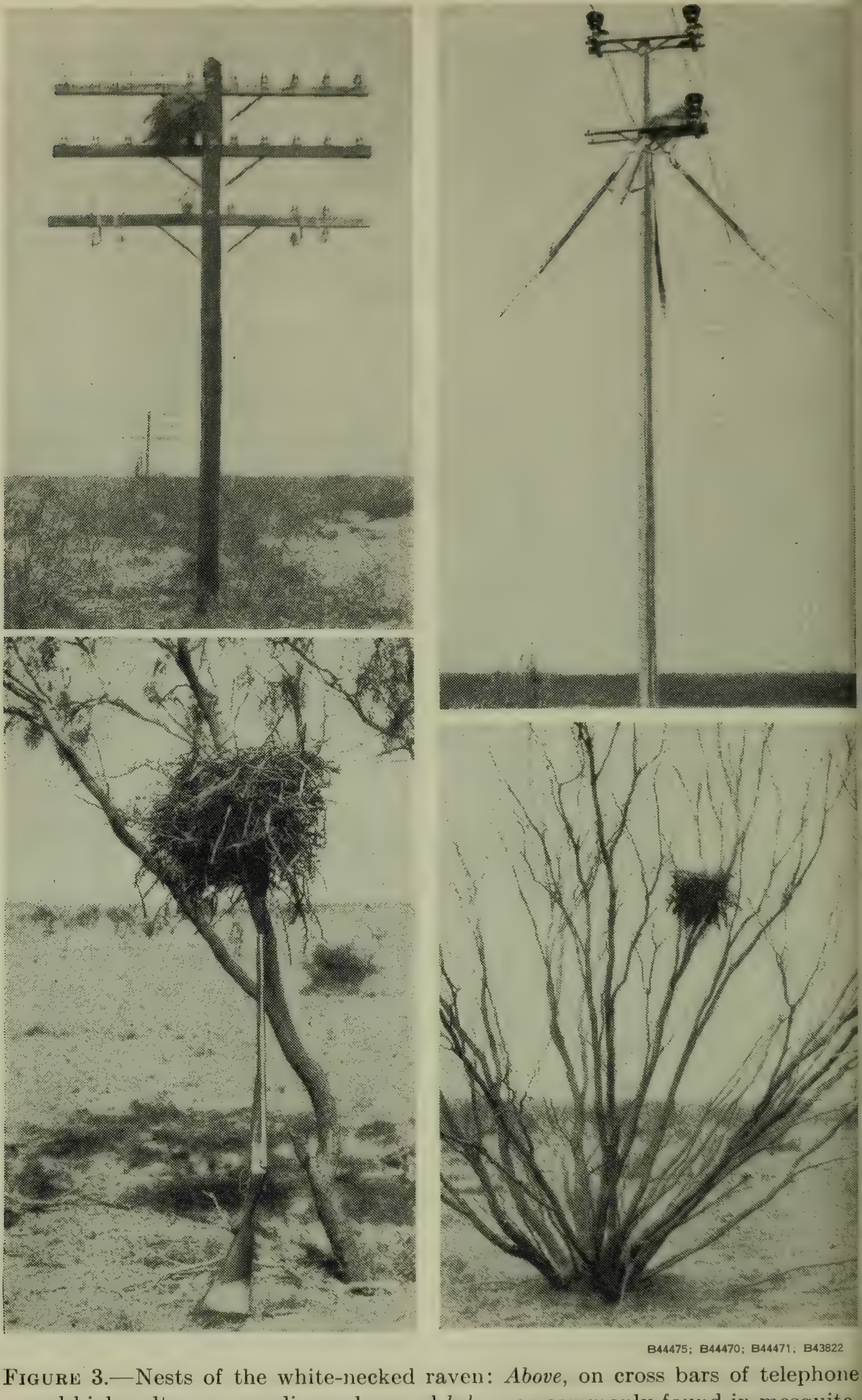
Activity around old nests begins in April, and sometimes the ravens stay constantly in the vicinity of chosen nests as if maintaining claim to them. Whenever old nests meet the birds' needs they are remodeled: old linings are discarded and frameworks repaired and fresh linings then installed. Entirely new nests are built at will, however. From the time the lining is completed until egg deposition commences, the nest is not protected from rains and the birds loosen up the lining after each shower, apparently so that the nest can dry more readily.

A variety of nest sites are chosen (fig. 3), the mesquite bush (*Prosopis glandulosa*) most commonly. Catclaw (*Acacia greggii*), allthorn (*Koeberlinia spinosa*), yucca (*Yucca* spp.), hackberry (*Celtis* sp.), mulberry (*Morus* sp.), oak (*Quercus* sp.), and pear (*Pyrus* sp.) are also used, and the ravens even build their nests in windmill towers and on cross bars of telephone and high-voltage power-line poles.

Nests are built above ground at heights ranging from 4 to 30 feet but usually between 7 and 10. They are constructed of dead twigs entwined into a platform about 12 inches wide and 12 to 24 inches deep with a rounded-out cavity in the top about 8 inches wide and 6 inches deep. This hollow is lined with some soft material, such as wool, cotton, rabbit fur, cow or horse hair, burlap, rags, binder twine, juniper bark, or yucca fibers, governed largely by what is readily obtainable.

EGGS

The writer's earliest record of fresh eggs is April 11, on which date in 1936 a rancher 30 miles south of Garden City, Tex., found and destroyed 2. His next earliest record is May 6, when in 1936 he found 3 fresh eggs near Vincent, Tex., but a nest found May 19, 1932, near Brownfield, Tex., contained 2 young about a week old and therefore had probably had eggs deposited in it about April 20. Bendire (1888: 555) reported May 6 as the earliest date eggs were found near Tucson, Ariz.; Clark (1899) recorded finding 5 eggs on April 18 at El Plomo, Sonora, Mexico; and Lloyd (1887: 290) reported 3 eggs found on May 5 in southern Texas. A crew of 8 men working in Lea County, N. Mex., from July 3 to 11, 1934, found and destroyed 314 eggs and 3,018 young—figures that illustrate the proportion of young to eggs in that month. The writer's examination between June 5 and 15, 1932, of 121 occupied nests revealed that 30 contained neither eggs nor young, 36, a total of 180 eggs in all stages from fresh to pipped, and 55, a total of 240 young. As Burns (1915: 285) states that the incubation period of the white-necked raven is 21 days, these findings may be interpreted to mean that the heavy egg laying occurs in May and most of the hatching in June.



B44475; B44470; B44471; B43822

FIGURE 3.—Nests of the white-necked raven: *Above,* on cross bars of telephone and high-voltage power-line poles; and *below,* as commonly found in mesquite, showing about minimum height nest is built above ground.

It is especially interesting that these birds so far south lay their eggs and rear their young at a later date than crows as far north as Canada. This is because the appearance of leaves on the mesquite trees and the period of grasshopper abundance, with which the egg deposition is closely associated, occur relatively late for a section so far south.

The eggs, from blue green to gray green in color, are marked with pale longitudinal streaks of drab to lavender gray and lilac irregularly splotched with various shades of brown. These markings serve to distinguish the eggs of the white-necked raven from those of all other North American Corvidae.

Clark (1899) records the measurements of 5 eggs; and Sherrill (1896) gives the average, maximum, and minimum measurements of 92 eggs in his possession and Bendire (1895) of 288 in the United States National Museum. Of these 385 eggs, the largest is 2 by 1.26 inches (Clark); the smallest, 1.52 by 1.09 (Bendire); and the average, 1.84 by 1.23 inches (46.74 by 31.24 mm.).

The number of eggs found in a nest ranged from 1 to 8, complements of 4, 5, and 6 occurring most frequently. In nests containing 3 or fewer eggs the clutches were in most cases probably not completed. The distribution of eggs found in 36 nests during June 1932 was as follows: 1 egg in each of 3 nests; 2 eggs in each of 2; 3 in 1; 4 in each of 4; 5 in each of 7; 6 in each of 15; 7 in each of 3; and 8 in 1. Bendire (1888: 556) states that from 4 to 7 eggs were laid to a set, 6 being found most commonly.

NESTLINGS

The number of nestlings found in a nest ranged from 1 to 7 and averaged 4.36 in 55 nests that contained young in June 1932.

When first hatched the young are naked, but in about a week they show pin feathers on the wings and uropygium and in about 3 weeks they are completely feathered and approximately two-thirds grown. They are of adult size before they leave the nest and shortly after they begin flying are not distinguishable from the adults except at close range, and then only by the light color of the gape of the beak and the newer-appearing plumage.

Three young that attempted to fly and successfully covered about 100 yards before striking the ground averaged 17 inches in total length, 10.16 inches in wing length, and 5.83 inches in length of tail.

BEHAVIOR AT THE NEST

Adult ravens are not aggressive in defense of their nests until after the young are hatched. During the construction of the nest and throughout the incubation period they will leave the vicinity of the nest long before a human intruder can reach it and it is usually difficult to get even within gunshot range of them. They rarely return to the nest directly; usually they circle closer and closer and finally alight in a nearby tree, to go to the nest later when the intruder is at a safe distance. After the young are hatched, solicitude of the parent birds becomes much stronger and continues to increase with the development of the nestlings until by the time the young are feathered the adults remain nearby and may actually swoop at anyone who gets too close to the nest. If a young bird can be made to squawk, which is usually a difficult task, the old birds will fly to within a few feet of the intruder and by their excited cawing soon attract a group of ravens, although usually only the parents come into close range.

During the first 2 weeks of life the nestlings stretch their necks upward and open their mouths upon hearing or feeling the least disturbance and will take food whenever and from whomever offered, but as they grow older they lie low in the nest when approached and even prematurely try to fly away.

ROOSTING HABITS

White-necked ravens, like crows, have the habit of congregating in large roosts for the night. Most commonly they choose thickets of large mesquite brush (fig. 4), preferably in natural depressions, such as creek bottoms, where they are somewhat protected from the wind. As mesquite is not always present or suitable, however, other vegetation must at times be used; and thickets of tamarisk (*Tamarix*), second growth cottonwood (*Populus*), and tornillo (*Strombocarpa*), as well as old orchards, are sometimes selected.

The manner and time of entering and leaving the roost vary locally and seasonally but in general are much the same, wherever the place or whatever the season. Late in the afternoon the birds start congregating at temporary gathering places some distance from the roost. From these, they leave in small groups that keep joining each other until continuous lines are formed drifting toward the roost. Disturbances, such as shooting, tend to break the line, but it is formed again after the birds have passed the point of disturbance. In the early flight lines much playful maneuvering takes place, but the later birds are more intent on getting to the roost and make a more direct flight. On cold or windy evenings the flight is direct and close to the ground, but on warm, quiet ones it is high and vacillating. The early arrivals rarely go directly into the roost but usually alight on the ground in nearby fields, so that it is common to see acres of the ground adjoining a large roost black with the birds.

The great massing preparatory to entering the roost has often been falsely interpreted as being indicative of large-scale depredations, for investigations on several occasions showed that the massed birds were

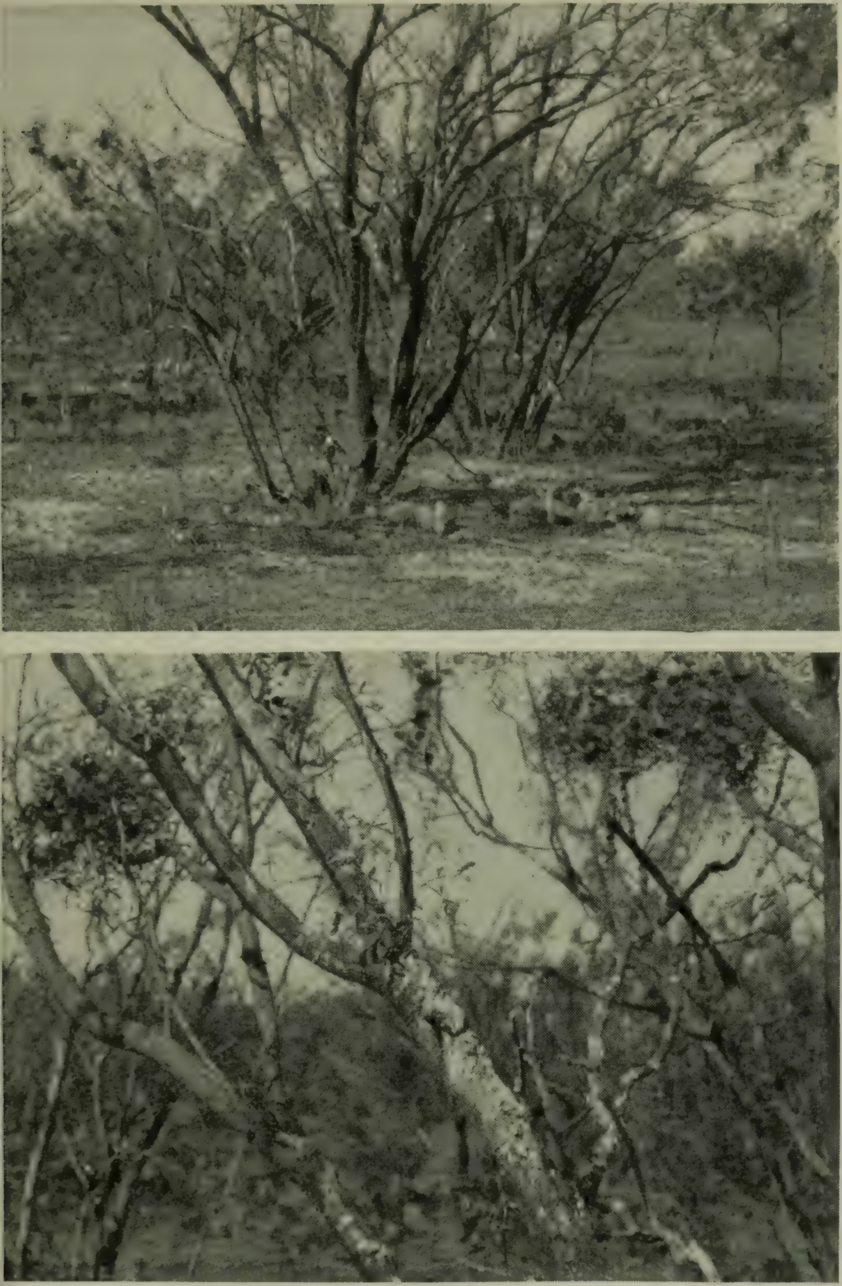


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FIGURE 4.—Typical mesquite pasture used by white-necked ravens for roosting site. The accumulation of excreta and pellets produces an offensive odor when wet and is a storehouse of weed seeds.

not feeding. Ravens that for two or three consecutive evenings covered the shocks of grain sorghum in a field next to their roost did no damage.

About dark the ravens leave the ground and enter the roost in one big influx. This is accompanied by considerable croaking and weird calls, some of which are so strange that if heard elsewhere they would not be associated with these birds. All the while the ravens are finding their roosting places and adjusting themselves, there is continual commotion and hubbub, caused by the crowding and unbalancing. The din is greatest when several large flocks attempt to settle in the roost at one time. Gradually the clamor diminishes and finally—after the last birds are settled in the roost—ends. Even after all is quiet, however, breaking branches or other disturbances cause an occasional brief outburst.

Once settled in the roost, the birds are so compactly massed it seems incredible that the brush will support them. Often the upper branches do break, and trees in which roosts have been used for some time have the tops leveled off like a trimmed hedge. Observed from above, an occupied roost gives the impression of a sea of black, broken only by occasional openings where the brush is thin or missing (fig. 5).

About half an hour before daybreak the birds start leaving the roost in small flocks, and by the time it is light most of them have departed for their feeding grounds. Those that leave before dawn usually fly until it is almost light before beginning to feed. Because of this habit less damage is inflicted on farms immediately surrounding the roost than on those farther away.

The daily cruising radius from the roosts probably averages somewhere between 5 and 15 miles, with most of the birds feeding within an 8-mile radius. A few birds from one roost that were traced night and morning were found to go 25 miles each way daily, which is undoubtedly about the maximum.

The number of birds in a roost varies in response to available food supplies and roosting sites. The long lines of birds entering various roosts afford means of obtaining a reasonably accurate estimate of roost populations, which range from 200 in a roost near Plains, Tex., to between 25,000 and 50,000 in one near Anson, Tex.

Supplementary roosting places can usually be found in the vicinity of each regular roost, and the birds resort to these whenever they are severely disturbed at the established roost. The new site may be used for one night or for several nights, or it may become a new regular roost if the disturbance at the old one is great and prolonged. Factors sufficiently potent to cause roost shifting include bombarding with guns or dynamite and cutting down the trees that harbor the roosts. The shifting of roosts from place to place during the course of years has often led to the mistaken idea that there are many roosts in a single community. Rarely, however, are regular roosts established closer to each other than 10 miles air line, even in the areas of heaviest concentration.

The general location of a roost can be ascertained by getting the direction of flight lines late in the evening and noting where they converge, and the exact place and size can be determined by finding the characteristic accumulation of excreta and pellets on the ground. Inasmuch as most roost sites are in mesquite, which has slight leaf litter, these signs loom up conspicuously (fig. 4). The quantity of pellet accumulation on the ground is an index both of the number of birds in the roost and of the length of time the roost has been used. Some old apple and locust trees noted in 1934 around a deserted home site in Lea County, N. Mex., where native trees are scarce, had been used so long as a roost site that the ground beneath them was covered to a depth of 6 inches with pellets and excreta. When wet these wastes often produce an offensive odor.

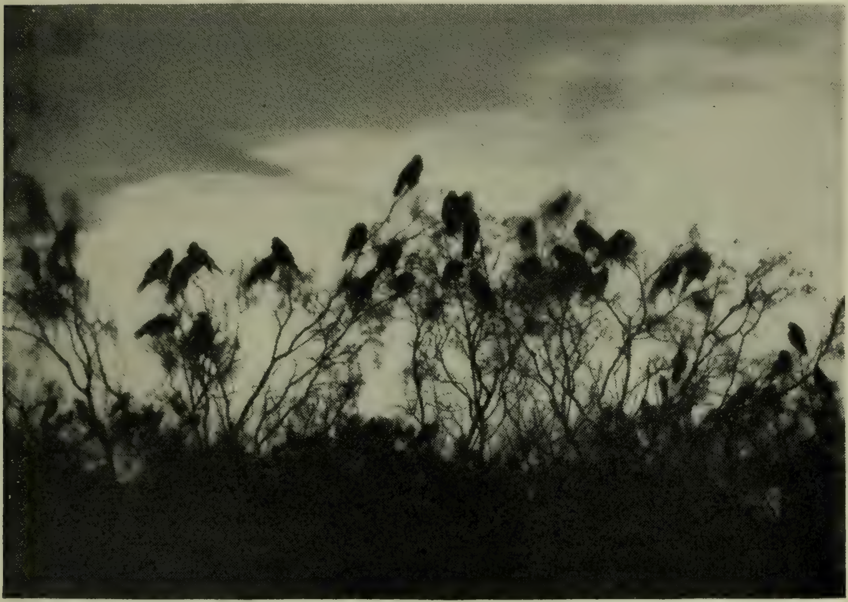
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FIGURE 5.—White-necked ravens in a roost. Note density.

MOVEMENTS

White-necked ravens are less migratory than crows, but some of them do drift back and forth for distances up to about 100 miles.

Residents in Baylor County, Tex., and also some in the extreme western part of the State report that the birds are numerous late in spring, in summer, and early in fall but are practically absent in winter. There is a short drifting late in spring from farming sections, where the birds winter, to mesquite pastures, their usual nesting grounds. There is seldom if ever a complete exodus of the birds from any area.

Banding studies have been the source of some information on the bird's movements. From November 1931 through December 1935 a total of 652 white-necked ravens—138 of them nestlings—were banded and released. Up to April 1938, 74 adults and 14 of the birds banded when nestlings had been retrieved. Figure 6 maps the drifting of the adults. Of 60 released from the station at Spur, Tex., 20 were retaken within 20 miles, at intervals up to 5⅓ years (2 birds) after their release. The longest elapsed time between banding and recapture of a bird was 6¼ years. The greatest distance traveled was about 250 miles air line, covered by an adult released at Spur in November 1931 and picked up 80 miles northwest of Del Rio, Tex., in October 1932. Of the 14 recoveries of birds banded as nestlings 1 occurred 45 miles from the point of release and all the others within 25 miles, 3 within 3 miles. Two of the birds were recovered 3½ years after banding and 2 others more than 5 years after.

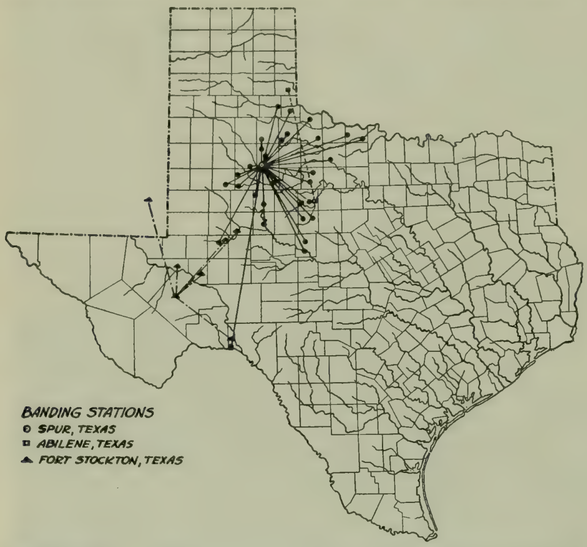

FIGURE 6.—Drifting of 74 adult white-necked ravens as revealed by banding studies.

From a group of ravens trapped at Abilene, Tex., on December 15, 1935, some were banded and released from the station the same day but seven were transported to Chickasha, Okla., and freed there on December 30. Of the seven, two were recaptured in Oklahoma—one at Enid just 9 days after its release and the other near Manguam at a point directly west of Chickasha and close to the Texas line about 6 weeks after being liberated. It is of interest that a month and a half after the latter capture one of the birds released from the Abilene station was taken at Wellington, Tex., within 25 miles of Manguam, as this may indicate that the spring and summer home of some of the wintering Abilene ravens is to the north, where these two, trapped together at Abilene but liberated 15 days apart at points 200 miles distant from each other, were recovered.

MOLTING

Only one molt was observed in the white-necked ravens, and it took place during August and September. Throughout the period, flight silhouettes commonly showed tail and wing feathers missing and the birds so bedraggled and different looking that many residents assumed they were either sick or extremely lousy. The solicitude usually shown by them for wounded fellows was almost entirely lacking. Moreover, the birds became so wary that it was almost impossible to get within shotgun range of them and the writer found it difficult to collect enough birds for stomach analysis, whereas at other times of the year he could easily shoot more than were needed.

PARASITES

White-necked ravens are heavily infested with a number of parasites. Without exception every bird examined showed some type of parasitism, but no ill effects on the hosts were noticeable. The more common species of parasites were preserved and identified.

All the birds examined were infested with biting lice (Mallophaga), among which *Menopon* sp., *Degeeriella secondaria*, and *Colpocephalum subaequale* were recognized.

Internal parasites were identified as follows: A filarial worm (*Diplotriaena* sp.) was common in the coelomic cavity, chiefly within the air sacs; heavy infestations of gizzard worms were found in many specimens; another roundworm (*Physaloptera* sp.—probably *galinieri*), was commonly found in the proventriculus; and the tapeworms *Raillietina* sp. and *Hymenolepis* sp. were present in the small intestines.

The intestines were also commonly infested with coccidian protozoa. No attempt was made to study the bacterial flora of the birds.

An interesting published record by Smith (1908) recounts his shooting a raven that was performing a strange circular flight and upon examining it finding "directly back of the eyes, and extending partly into the brain, a parasite more than an inch in length, about the thickness of wrapping twine, pale yellow in color." The parasite was not identified, but it was probably the larval stage of a fly, perhaps a screwworm.

DAMAGE CAUSED BY RAVENS

CROP LOSSES

Because of their appetites and gregarious habits white-necked ravens are capable of causing severe damage to cultivated crops. The birds congregate close to farming districts for about 8 months of the year, being absent from them only during the nesting season, which they usually spend in the open brushland pastures until the young are old enough to join the flock.

The amount of damage varies locally according to the crops grown, seasonal conditions, climatic variations, and roosting facilities available. The greatest losses inflicted are upon grain sorghums, corn, melons, and peanuts. Less damage is usually done to pecans, fruits, truck crops, small grains, poultry, sheep, and game and song birds. Crop losses are discussed in the account of food habits.

FARM-TO-FARM CANVASS

In order to obtain the farmer's point of view regarding the raven, a farm-to-farm canvass covering 100 farms was made in Howard County, Tex., in April 1936. This county is typical of western Texas, where the ravens are an agricultural problem. The same questions were put in each interview as follows:

1. What acreage of grain sorghums do you usually grow?
2. What is your estimate of the yearly loss to your grain sorghum crop caused by the ravens?
3. Which of your crops suffer the greatest monetary loss due to ravens?
4. Do you think the ravens should be controlled in your vicinity?
5. Who do you think should pay for any raven control work that might be inaugurated?
6. Would you personally contribute toward the costs of a control program?
7. Are you opposed to the use of poison or its exposure on your premises for controlling ravens?

The 100 farmers interviewed estimated that they grew about 13,644 acres of sorghum each year, and every farmer but one considered that the greatest loss the ravens caused him was to this crop. The estimated annual loss per acre ranged from nothing to \$3 and averaged \$0.66. At this average rate the annual loss from the total acreage of grain sorghums grown in Howard County would be \$49,500.

Control in their own communities was considered necessary by 93 farmers; and control in the county as a whole but not in their immediate vicinities, by 7. Willingness to contribute toward the cost of control was voiced by 73, but 27 either were unwilling to pay or considered their losses too small to justify the expenditure.

As to poison, 85 farmers had no objection to using it or to having it exposed on their land for controlling birds; the others feared that it might poison livestock or game and preferred other, more selective, methods of control.

The farmers in general were opposed to ravens more because of the watermelon losses they caused than because of the losses to grain, although the latter were many times greater. One farmer expressed this attitude by saying that he would rather have the ravens destroy a hundred dollars' worth of his feed crop than ruin his little melon patch.

The following opinions comparing the ravens with other pests were volunteered. Six farmers considered small birds—including lark buntings, English sparrows, and blackbirds—more detrimental than ravens to the grain sorghum crop; two thought that rabbits were as bad as ravens and two thought them worse; two believed that ducks consumed more grain sorghums than ravens; and two said that coyotes were more destructive than ravens to their melons.

DISSEMINATION OF DISEASES

Because they are more buzzardlike than crows in their carrion-eating proclivities, white-necked ravens are often accused of being important disseminators of contagious diseases of livestock and poultry, chief among which are hog cholera, blackleg, and roup. Possibly this is true, but nothing definite is known about the matter. The sanitary disposal of all carcasses, however, will largely reduce the possibility of raven-borne diseases. It must be remembered that other animals also—dogs, cats, wild flesh-eaters, and numerous insects, for instance—are all potential spreaders of diseases and that sanitary measures will produce quicker, cheaper, and more complete protection than any attempt to control all the potential carriers.

INTERFERENCE WITH TELEPHONE SERVICE

In 1930 the Bell Telephone Co. of Denver, Colo., reported trouble with "crows" on a line constructed in 1929–30 between Denver and Lamar as part of the long distance hook-up across the United States. The "crows," which it has since been determined were white-necked ravens, had adopted the cross arms of the telephone poles as nesting sites, and their nests were causing short circuits. There is still trouble, almost 95 percent of it within a 72-mile stretch beginning about 15 miles northwest of Lamar and extending toward Denver. The greatest concentration of ravens seems to be along and near Big Sandy and Rush Creeks, between the towns of Eads and Boyero, a relatively flat, dry, and treeless area. It is the lack of tree growth that makes the poles attractive nesting sites, and the short circuits are caused by the old barbed wire fences and hay wire discarded by the farmers and used by the ravens as part of their nesting material.

Ever since the trouble started, the company has had a crew of 4 men patrol this section daily between March and July each year in an attempt to keep the line clear and has tried various control and prevention devices, at a total annual cost of $2,500 to $5,500. There have been as many as 202 instances of wire trouble that called for special investigation in a year (1934), and between 700 and 800 pounds of scrap wire have been removed annually from the nests and the ground beneath the lines. Shooting, poisoning, and trapping have accounted for 1,500 to 2,000 ravens yearly, but the trouble persists. The most satisfactory short-circuit preventive tried so far is the insulation of the wires with a split rubber hose for about 30 inches out from each side of the cross arm.

FOOD HABITS

NUMBER AND DISTRIBUTION OF STOMACHS

Laboratory analyses were made of the contents of 827 white-necked raven stomachs—707 adult and 120 nestling—collected in 4 States and in every month. The numerical distribution of the stomachs by States was as follows: *Adult*—10 Arizona, 14 New Mexico, 3 Oklahoma, and 680 Texas; *nestling*—16 Oklahoma and 104 Texas. The numerical monthly distribution was as follows: *Adult*—17 January, 68 February, 73 March, 102 April, 65 May, 42 June, 6 July, 26 August, 66 September, 158 October, 59 November, and 25 December; *nestling*—8 May and 112 June.

As the bird's range is relatively small, as most of the stomachs were taken from densely inhabited areas, and as enough stomachs to give a good indication of the monthly food preferences were available for every month except January and July, the data obtained from the stomach analyses are considered fairly representative of the bird's food habits.

FOOD OF ADULTS

Both stomach analyses and field observations showed that white-necked ravens are omnivorous and can usually be found feeding where the greatest abundance of palatable food is available. The animal and vegetable portions of the adults' food were practically equal but varied materially with the seasons. The monthly volume and occurrence percentages of the principal food groups are given in table 3 in order of volumetric importance, and the volumetric food percentages are shown graphically in figure 7. An itemized list of the foods, arranged in systematic order, is given in table 5 (p. 47).

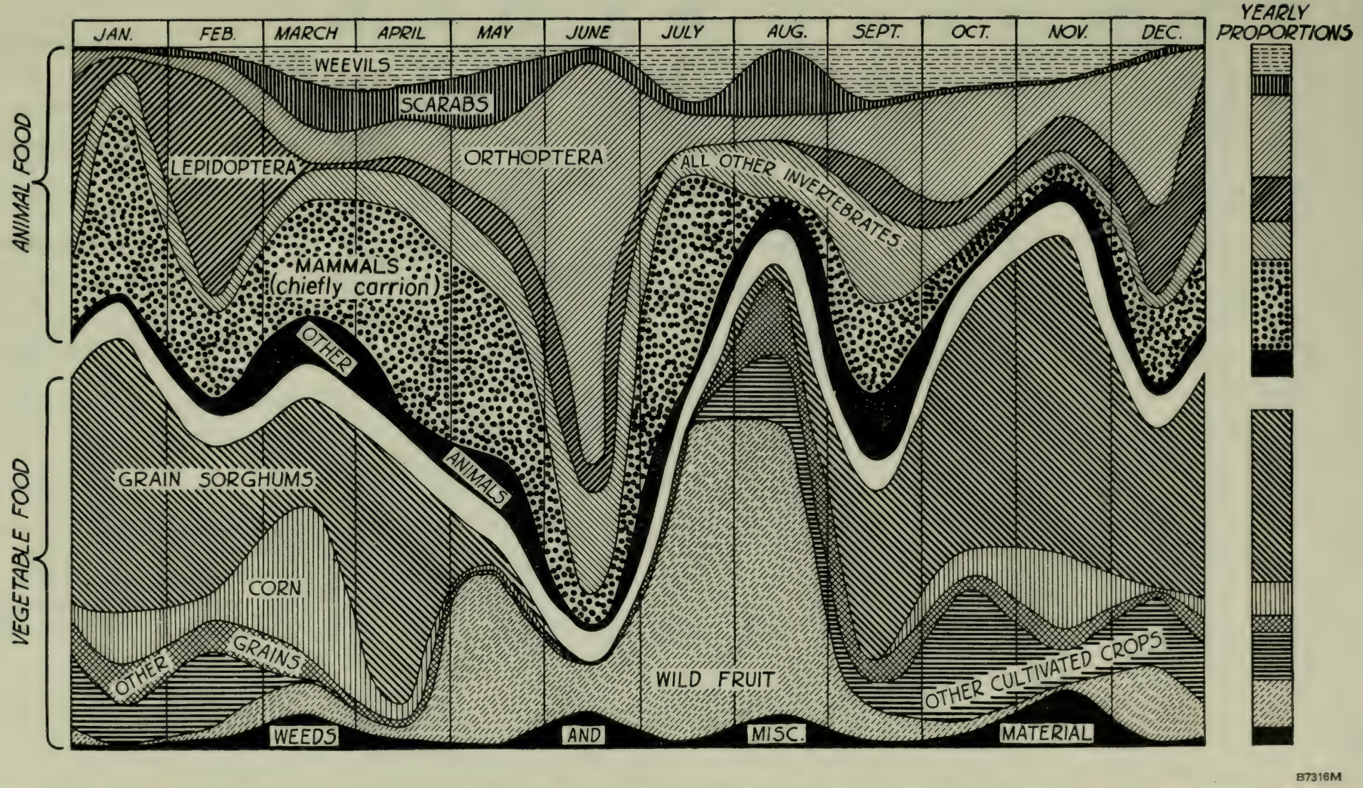

FIGURE 7.—Food of 707 adult white-necked ravens, showing the varying quantities of the principal items from month to month and the yearly average of each. Figures for both volume and occurrence percentages are given in table 3.

TABLE 3.—*Monthly and yearly volume and occurrence percentages of the principal food groups in the diet of 707 adult white-necked ravens*

[Roman figures indicate volume percentages; italic, occurrence percentages. The former are presented graphically in fig. 7]

Food group	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly average [1]
ANIMAL FOOD													
Insects:													
Grasshoppers and allies (Orthoptera)	1.50 *29.41*	3.76 *52.35*	5.68 *42.47*	5.39 *56.86*	12.34 *49.23*	60.32 *90.48*	5.17 *33.33*	13.65 *53.85*	7.86 *30.30*	16.23 *77.85*	5.31 *49.15*	22.58 *88.00*	12.56 *56.01*
Beetles and weevils (Coleoptera):													
Weevils (Curculionidae)	[2] *5.88*	1.15 *27.94*	5.33 *45.21*	5.79 *51.96*	3.05 *27.69*	.12 *9.52*	8.33 *16.67*	[2] *3.85*	8.03 *37.87*	6.19 *47.47*	5.36 *61.02*	1.00 *28.00*	4.49 *38.61*
Scarab beetles (Scarabaeidae)	.06 *5.88*	.46 *8.82*	6.43 *31.51*	5.30 *43.14*	8.36 *40.00*	2.41 *30.95*	1.67 *33.33*	.77 *11.54*	1.65 *19.69*	.89 *5.06*	.15 *1.69*	.63 *16.00*	2.77 *20.37*
Other beetles	.13 *25.53*	.06 *4.41*	1.62 *36.02*	1.56 *32.35*	1.00 *31.82*	3.61 *28.57*	3.66 *33.34*	.35 *34.60*	11.14 *62.12*	1.50 *35.57*	1.15 *15.25*	.46 *32.00*	2.29 *30.26*
Total Coleoptera (volume)	.19	1.67	13.38	12.65	12.41	6.14	13.66	1.12	20.82	8.58	6.66	2.09	9.55
Moths and caterpillars (Lepidoptera)	2.06 *41.18*	31.70 *64.71*	.66 *24.66*	2.42 *23.53*	6.17 *32.31*	3.83 *14.29*	------ ------	------ ------	6.94 *16.67*	3.50 *21.52*	4.98 *5.25*	13.54 *72.00*	6.64 *27.16*
Other insects [3]	5.06 *47.06*	1.60 *26.47*	2.94 *54.79*	4.15 *71.57*	5.15 *60.60*	7.00 *42.86*	.83 *33.33*	7.49 *34.60*	2.92 *24.24*	1.03 *29.68*	.64 *15.25*	.87 *60.00*	2.93 *19.09*
Total insects (volume)	8.81	38.73	22.66	24.61	36.07	77.29	19.66	22.26	38.54	29.34	17.59	39.08	31.68
Mammals, chiefly carrion	28.13 *70.59*	12.94 *42.65*	17.33 *65.75*	29.41 *76.47*	24.19 *58.46*	4.93 *19.05*	31.67 *50.00*	.54 *15.38*	13.76 *36.36*	4.47 *15.19*	2.49 *10.17*	11.29 *16.00*	13.63 *39.32*
Other vertebrates [4]	1.25 *12.50*	2.33 *19.20*	7.02 *28.68*	2.89 *25.42*	7.69 *21.47*	.78 *21.40*	.83 *16.66*	4.39 *23.00*	9.85 *27.22*	.96 *6.33*	3.06 *22.00*	1.96 *16.00*	3.76 *19.40*
Other invertebrates [5]	[2] *5.88*	.97 *11.76*	.04 *19.19*	.30 *24.51*	.99 *27.20*	4.73 *42.86*	[2] *33.33*	.31 *7.59*	.08 *7.57*	.14 *14.55*	.17 *5.08*	.29 *28.00*	.60 *17.68*
Total animal food (volume)	38.19	54.97	47.05	57.21	68.94	87.73	52.16	27.50	62.23	34.91	23.31	52.62	49.67
PLANT FOOD													
Grains (Gramineae):													
Grain sorghums	41.06 *70.59*	21.74 *67.65*	16.92 *53.42*	36.07 *63.73*	3.80 *20.00*	------ ------	------ ------	2.58 *30.77*	24.83 *60.61*	35.63 *55.06*	48.19 *77.97*	23.79 *80.00*	25.66 *53.04*

Corn	8.25 *11.76*	4.08 *10.29*	22.07 *43.84*	2.66 *10.78*	1.14 *7.69*	-------- --------	-------- --------	-------- --------	-------- --------	4.44 *8.86*	10.86 *22.03*	.13 *8.00*	5.28 *12.16*
Other grains	5.81 *29.41*	4.66 *22.06*	3.82 *26.03*	.81 *6.86*	.09 *6.15*	.02 *2.38*	-------- --------	11.15 *30.77*	3.12 *10.61*	1.36 *6.96*	2.96 *10.17*	1.34 *12.00*	2.41 *12.16*
Total grains (volume)	55.12	30.48	42.81	39.54	5.03	.02	-----	13.73	27.95	41.43	62.01	25.26	33.35
Other cultivated crops	5.94 *6.25*	11.41 *20.60*	.10 *9.59*	-------- --------	-------- --------	-------- --------	-------- --------	10.70 *19.20*	3.93 *16.67*	19.70 *54.40*	5.78 *18.65*	10.21 *28.00*	7.27 *20.14*
Wild fruits	(2) *5.88*	1.38 *10.29*	4.53 *10.96*	2.11 *19.61*	25.54 *50.77*	6.74 *23.81*	47.01 *83.33*	43.11 *73.08*	5.00 *15.15*	2.20 *7.59*	.31 *5.08*	11.29 *44.00*	7.00 *19.66*
Miscellaneous seeds	.75 *50.00*	1.76 *20.60*	5.51 *47.90*	1.14 *26.42*	.49 *16.92*	5.51 *21.40*	.83 *16.67*	1.96 *15.38*	.89 *21.20*	1.76 *26.59*	8.59 *33.95*	.62 *36.00*	2.71 *27.50*
Total plant food (volume)	61.81	45.03	52.95	42.79	31.06	12.27	47.84	72.50	37.77	65.09	76.69	47.38	50.33

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[1] Obtained by dividing total volume of food by total number of stomachs; not by adding average percentages for each month and dividing the total by 12.

[2] Trace.

[3] Hemiptera, Hymenoptera, Diptera, Isoptera, Neuroptera, and Odonata.

[4] Birds and their eggs, reptiles, amphibians, and fishes.

[5] Arachnida, Oligochaeta, Gastropoda, and Myriapoda.

ANIMAL FOOD

About half (49.67 percent) the food of the adult white-necked ravens was composed of an assortment of animal matter, including earthworms; spiders and scorpions; centipedes and millepedes; insects; snails; amphibians; reptiles; birds and bird eggs; and mammals, chiefly carrion. The animal diet was greatest during June while the birds were rearing their young and least in November when the birds could more easily obtain vegetable material (mostly grain sorghums).

INSECTS

One of the greatest benefits of birds to man is their destruction of harmful insects; and so, in order to appraise a given bird, one should know how many and what kinds of insects it destroys and weigh this evidence against its detrimental habits. In the present study insects contributed the greatest bulk of any class of animal food eaten by the adult white-necked ravens and were consumed by the birds during every month. Nearly two-thirds (63.78 percent) of the animal food and almost a third (31.68 percent) of the entire food consisted of insects. The year-round consumption was possible because of the mild winter climate that prevails over most of the bird's range. Even in midwinter there are warm days when a few insects are active and ground forms usually may be obtained by turning over ground litter, such as cow chips and small rocks.

The economic importance of insects in the raven's diet can be demonstrated only by separate discussion of the various types consumed. The following monthly consumption percentages of insects as a whole are of interest, however, as showing variations in response to the progress of the seasons: January, 8.81; February, 38.73; March, 22.66; April 24.61; May, 36.07; June, 77.29; July, 19.66; August, 22.26; September, 38.54; October, 29.34; November, 17.59; and December, 39.08. The insect foods are discussed in the order of their volumetric importance. The species identified are listed in table 5 (p. 47).

Orthoptera.—Grasshoppers and their allies ranked first among the insect foods in both volume and frequency of occurrence, forming 12.56 percent of the entire food, or 39.65 percent of the insect food, and being found in 56.01 percent of the stomachs. In eight stomachs (one taken in May, five in June, and two in September) they were the only food present. They were eaten during every month, reaching their high in both volume (60.32 percent) and occurrence (90.48 percent) in June, when the parents not only fed them to their young (p. 42) but themselves subsisted largely on them. They dropped to a low in the diet (1.5 percent) in January but even then were found in 29.41 percent of the stomachs.

The greater part of the orthopterous diet was composed of grasshoppers, which were represented chiefly by short-horned Acrididae although many long-horned Tettigoniidae also were identified. Of the 707 adult stomachs examined, 339, or 48 percent, contained 2,435 grasshoppers, an average of more than 7 a bird for those that ate them and of 3.4 a bird for the entire lot. If the data obtained from the nestling stomachs (p. 42) were incorporated, the average would be raised materially. From the figures given it is apparent what a beneficial effect thousands of ravens might have in reducing the grasshopper population.

The monthly grasshopper consumption was greatest in June, as the insects were then at their peak. It dropped off sharply in July, the small percentage for that month being due no doubt to the small number of stomachs available. If a larger series had been studied, the decline would probably have been less abrupt. Quantity variation in the grasshopper part of the diet was brought about also by the development of crops and the early maturing of wild fruits that decoyed the birds from the insects. In September both grasshoppers and fruit were reduced in the diet and the early maturing grain sorghums were compensatingly increased. In October, the month when most of the early grain sorghums are ripe and less palatable than in the dough stage and the early fruits are mostly gone, the birds again ate more grasshoppers.

The role that white-necked ravens play in grasshopper consumption can easily be seen in irrigated areas like that about Fort Stockton, Tex. While the farmers are irrigating their alfalfa fields, the spreading water keeps grasshoppers and other insects moving and there is always a group of white-necked ravens following the flow and catching the insects. Freshly mowed alfalfa fields also are visited by hordes of the birds seeking grasshoppers and other insects that are more easily caught when the vegetation is flat on the ground. In mesquite pastures from June until October it is common to see ravens jumping around in all directions to catch grasshoppers.

That many farmers, however, are not aware of the value of the white-necked ravens in destroying these grasshopper pests, is shown by the common assertion that they know of no good these birds do. One farmer, when informed of the grasshopper-destroying activities of the bird remarked that he was more convinced than ever that ravens were of no value because there were not enough grasshoppers for his turkeys as it was.

Other orthopterons commonly found in the adult raven stomachs were crickets, mantids and their egg cases, and phasmids (walking sticks). The adults of these species were eaten in summer, but the egg cases of the mantids were taken largely in fall and winter.

As orthopterous insects have wrought more damage to plant life in the range of the white-necked raven than any other insect group, the raven's consumption of them is a definite point in the bird's favor.

Coleoptera.—Beetles were the second most important insect group in the food of the adult ravens, as they contributed 9.55 percent of the total subsistence, or 30.14 percent of the insect food. In all, 16 families were identified.

Weevils (Curculionidae), the most frequently eaten beetle food, furnished 4.49 percent of the entire diet, or 47.02 percent of the coleopterous food, and were noted in 38.61 percent of the stomachs. Remains of 2,835 individuals of 12 genera were found, more than 100 being present in each of 6 stomachs, 1 of which held 268. The four most common genera were *Ophryastes*, *Eupagoderes*, *Thecesternus*, and *Cleonus*.

Scarab beetles (Scarabaeidae), comprising dung beetles, leaf chafers, and others, came next. They supplied nearly 3 percent of the yearly diet, or about 29 percent of the beetle food, and were taken in every month, in greatest quantity in spring. Of the 11 genera represented, *Phyllophaga* (May beetles) and *Canthon* (tumblebugs) were commonest. Adult and larval May beetles occurred in more stomachs (80) and in greater volume than all the other Scarabaeidae present combined; and tumblebugs were found in 41 stomachs, in some of which they were an important part of the contents. Half of one raven's last meal consisted of 17 adult *Phyllophaga* and 10 *Canthon* specimens. Inasmuch as the scarabs as a group are predominantly harmful, the raven's consumption of them is to the bird's credit.

The 14 other beetle families, of which the Carabidae and Tenebrionidae were most prominent, were found in smaller quantities, aggregating only 2.29 percent of the birds' whole food, or 23.98 percent of the coleopterous diet. Of these 14 families, 7 (Anthicidae, Cebrionidae, Tenebrionidae, Cerambycidae, Buprestidae, Chrysomelidae, and Elateridae) are considered detrimental; 5 (Hydrophilidae, Dermestidae, Histeridae, Staphylinidae, and Nitidulidae), of neutral significance; and only 2 (Cicindelidae and Carabidae), beneficial.

Lepidoptera.—Moths and caterpillars ranked next lower than beetles in the adult raven's diet, averaging 6.64 percent of the entire food and being identified in 192, or 27.18 percent, of the stomachs. These insect pests, 6 families of which were identified, were eaten in every month except July and August but were taken most extensively during winter, when cutworms (Phalaenidae) predominated. More than 75 of these were found in each of 8 stomachs taken during February, 275 in 1 of the 8. During December, pupae and larvae of *Datana* sp. (oakworms) of the Notodontidae family were the dominant forms although cutworms also were evident.

Field observations revealed the source of some of these insects and the time of year eaten. During the winter it was common to see a hundred or more white-necked ravens feeding on the ground in cattle pastures. Although their presence there could not at first be explained, it was later noticed that almost every cow chip and small object on the ground had been turned over. A few of the larger chips that the birds could not manipulate were investigated, and beneath at least 75 percent of them cutworms were disclosed; 1 chip harbored 11. A number of farmers have told the writer that on several occasions these ravens have eaten so many cutworms in their young cotton as to obviate the usual necessity of replanting the crop; and many farmers in the irrigated alfalfa areas attest that these birds are a decided benefit in protecting the crop from the alfalfa caterpillar.

Although the cottonworm (*Alabama argillacea*) was not positively identified in the stomachs examined, many digested remains of larvae and adults similar to it were found that probably were that species. Early in September 1934 flocks of ravens were constantly being flushed from cottonfields. At first it was assumed that the birds were resting there, but close scrutiny disclosed that they were walking down the cotton rows looking from side to side, apparently in search of the worms. Moreover, the birds were observed only in cottonfields that were badly worm-infested.

Surely from man's point of view the lepidopterous part of this raven's diet can be listed among the bird's better qualities.

Hemiptera.—Bugs and leafhoppers (included in Other insects, table 3) were found in 171, or 24.19 percent, of the stomachs but formed only 1.51 percent of the entire food. Eaten in small quantities throughout the year, they attained their highest monthly food percentages during May and June. The variety taken was great, as forms of 28 genera were identified. Pentatomidae (stinkbugs), noted in 109 stomachs, were represented by more species than any other family of this order and were taken in greater volume and larger numbers than all the other Hemiptera eaten combined. Leafhoppers (*Stictocephala festina*), of the Membracidae, occurred quite frequently in the fall stomachs, reaching a high in October, when they appeared in 22 of the 31 stomachs that contained hemipterons, in 1 of which 203 leafhoppers constituted 40 percent of the contents. Forms of Cicadidae (harvest flies) and Reduviidae (assassin bugs) were unimportant food items, both in quantity and in frequency of occurrence. The squash bug *Anasa tristis*, of the Coreidae, was identified in a single stomach.

Although some of the Hemiptera eaten are harmful plant feeders, others are useful predators, so that the economic status of the raven is not greatly affected by the mixed diet.

Other insects.—The remaining 5 orders of insects found in the adult stomachs made up only 1.42 percent of the food. They comprised Hymenoptera (bees, wasps, ants, etc.), Diptera (two-winged flies), Isoptera (termites), Neuroptera (lacewing flies, ant lions, etc.), and Odonata (dragonflies and damsel flies). The Hymenoptera taken, of which 11 families and 20 genera were identified, were mostly small ants that were probably eaten accidentally while adhering to other foods or while contained within the stomachs of such foods as lizards and amphibians. The parasite *Brachymeria ovata* was present in every case with pupal specimens of the *Datana* moth, and it, as well as the other Chalcidae and parasitic Ichneumonidae noted, probably was ingested with lepidoterous food items. The Diptera were not all identified beyond the 8 families noted, but 5 genera were recognized, mostly larval and pupal forms that were associated with carrion taken by the birds. The Isoptera consumed were unimportant as food because of their small size. Some of them may have been eaten incidentally with other foods. The Neuroptera were represented by one occurrence of an aphis lion (*Chrysopa*) and the Odonata by a single damsel fly (Zygoptera).

The economic importance of these five insect orders is so varied and the quantity of them taken was so small that their presence in the raven's diet does not greatly affect an estimate of the bird's economic status.

ARACHNIDA

Spiders and their allies (table 5, p. 47) were frequent items in the summer diet of the adult birds but composed less than 2 percent of the food volume for that period. Araneae were found in 7 percent of the stomachs, most of which were collected during the nesting season. As the spiders' soft bodies doubtless hasten the ravens' digestion of them, the record of the frequency of their occurrence may be more informative than that of their volume. Only spiders of the family Lycosidae were recognized; undoubtedly other families were present, but most of the material was in a condition too fragmentary for identification. Harvestmen, or daddy longlegs (Phalangiida), were found in only 7 stomachs and so are not an important food even though 1 bird had eaten 35. Solpugids, which because of their soft bodies were detected mostly by their chelicerae, occurred in 29 stomachs, comprising only a trace of the contents in most of them but forming 10 percent of the volume in 2. Scorpions were identified in 10 stomachs but supplied only a very small part of the contents.

The quantity of Arachnida eaten by the adult birds was so small that very little economic significance can be attached to it. In the nestling diet, however, spiders composed a much larger percentage of the food volume and occurred much more frequently (p. 43).

OTHER INVERTEBRATES

Of the invertebrates eaten exclusive of insects and Arachnida the lowest form recognized in the adult raven stomachs was an earthworm (Oligochaeta). A few snails (Gastropoda) were found, but the remains were mostly fragmentary. Some Myriapoda (both centipedes and millepedes) were noted frequently, but usually in small quantities.

MAMMALS, CHIEFLY CARRION

Mammals, mostly carrion, were the second largest group in volume (13.63 percent) among the animal foods of the adult ravens and occurred in 278, or 39.32 percent, of the stomachs. They were taken in every month, with the 3 highest monthly volumetric percentages being recorded for July, April, and January (table 3; fig. 7). In all, 14 mammalian genera were identified (table 5, p. 47).

The cow remains and also many of the unidentified carrion items were found in stomachs collected in August and September 1934, when large numbers of cattle were being slaughtered in the program of drought relief. The carcasses in the fields and the huge bone piles at the emergency canneries attracted large flocks of ravens and so played an important role in reducing raven damage to crops in those areas. Most of the sheep remains were found in stomachs obtained in April and May during the lambing season, the period of greatest natural sheep losses, when the abundant food supply made available by the dead animals draws large numbers of ravens. The single dog and skunk occurrences, as well as many of the rabbit and rodent items were probably highway carrion.

Rabbits.—Rabbits were consumed more frequently than any other mammal. They were identified in 125, or 17.68 percent, of the stomachs as follows: *Sylvilagus* spp., in 11, *Lepus californicus* in 2, and undetermined rabbit in 112. In 8 of the stomachs immature animals were found and in 1 an embryo. The immature specimens may represent kills made by the ravens, but it is doubtful whether mature rabbits often are attacked by the birds. The adult jack rabbits eaten probably all represent carrion, as it is common to see white-necked ravens feeding on rabbits and other animals that have been killed along highways.

Rodents.—The squirrels, kangaroo rats, and other rodents consumed might also have been highway carrion, or they could have been picked up after rodent control campaigns. White-necked ravens commonly flock to prairie dog towns that have been treated with poison grain and feed on the dead animals. They relish the eyes particularly, so that by 10 o'clock the morning after a poison treatment it is almost impossible to find a dead rodent that has not had its eyes pecked out. In all, rodents of seven genera were eaten by the ravens but by so few that the effect of these birds on control of rodent populations is probably of little consequence.

Raven-sheep relationship.—Serious complaints of raven damage to sheep are confined mostly to Midland, Glasscock, Upton, and Reagan Counties, Tex., for although areas to the east, west, and south of these counties also support many sheep, the ravens there are so scattered that the damage they might do is negligible. These particular counties have a greater raven population and consequently a greater sheep loss because they are just south of one of the bird's heaviest winter concentration areas and because they provide not only splendid nesting sites but also an abundant food supply early in spring when sustenance in the winter home is becoming scarce. The principal food attraction is the large number of dead sheep and lambs.

Early spring is the critical time for sheep, as the ewes, heavy with lamb, may be weakened by the limited food supply. The death rate at that time, ordinarily high, in recent years has been increased by losses from bitterweed poisoning, so that mortality among the ewes and newborn lambs is considerable. Moreover, during delivery the ewes often become partially paralyzed and when this occurs make no attempt to protect themselves, thus becoming subject to raven attack (fig. 8). Although the ravens do eat dead and decaying flesh they prefer fresh meat, and this often leads to their preying upon newborn lambs that are not yet able to get up and defend themselves. However, information obtained from the sheepmen and observations made by the author prove conclusively that the birds attack only the weaker lambs, most of which would have died anyway.

The first objective of attack by the birds is the eyes, and by 10 a. m. scarcely a dead lamb can be found in the pastures that has not at least one eye missing and more than likely both (fig. 8). The tongue, navel, and rectum are also attacked by the birds, but it is the raven's insatiable liking for the eyes that places the bird on the sheepman's black list. At times the birds remove the eyes even before the animals are dead.

The sheepmen have no accurate or uniform method of telling whether the dead lambs with eyes missing were killed by ravens or of determining whether the eyes were removed before or after death. Some sheepmen think that the lambs with blood around the eyes are raven victims; others believe that only those with the eyes out and the body not yet rigid have been killed by the birds; and still others are of the opinion that practically all dead lambs are raven kills.

A cross section of the opinions of the sheepmen regarding ravens was obtained by interviewing 51 individuals in Glasscock and Upton Counties, Tex., in April 1936. These men owned about 114,600 sheep on 366,720 acres of land. Their 85,950 bred ewes were expected

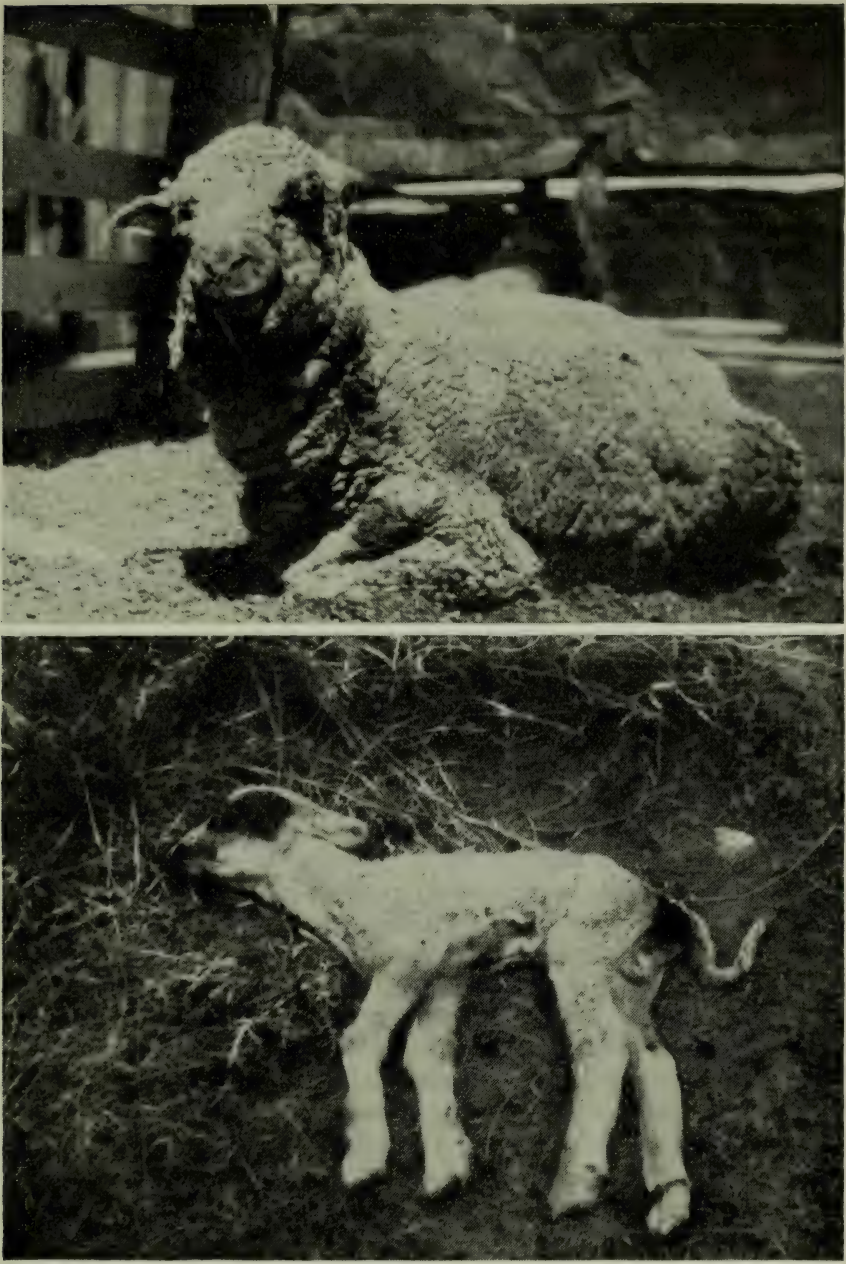

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FIGURE 8.—*Above*, Ewe with one eye pecked out by ravens while she was in labor; *below*, dead lamb from which ravens have removed eyeball, tongue, navel, and rectum.

to drop about 81,650 lambs during the spring, as in the opinion of a number of sheepmen an average of 95 lambs is born to each 100 ewes that are bred.

The 51 estimates of the percentage of lambs that would not otherwise have died that are killed annually by ravens ranged from 0 to 8 and averaged 1.2 percent. Estimates in the area where the more serious losses occurred averaged 2.4 percent, just double that for the whole region studied. Sheepmen in this area report raising between 65 and 75 percent of their annual lamb crop, which means that between 35 and 25 percent of all lambs born are lost from all causes. Even if the larger percentage, 2.4, is deducted as representing the lambs killed by ravens, it still leaves from 32.6 to 22.6 percent of the lamb deaths to be accounted for. The sheepmen all agreed that the principal cause of lamb loss to ravens is adverse weather, as cold spells during spring cause the newborn lambs to "chill down" and thus make them more vulnerable to bird attack.

Many sheep in the area studied die annually from the effects of screwworm infection and bitterweed (*Actinea odorata*) poisoning, and the consensus of the 51 sheepmen was that losses from both these causes were greater than from raven depredations. As an aid in abating screwworm abundance the ranchers are advised to dispose of all dead animals, either by burying or by burning. The sheepmen in the raven territory are extremely lax in this respect, and were it not for the ravens' consumption of carrion much more of it would be left as an inviting home for screwworms. This good that the ravens do may in part compensate the rancher for the losses they inflict.

About half the sheepmen considered their losses from ravens serious enough to justify paying for control; the rest either doubted that control was necessary or objected to paying for it because they thought the losses did not warrant the expense.

The remedies for raven depredations on sheep are: Control of the birds, which can be accomplished by trapping and nest destruction (see Control Measures, p. 53); and improvement in lambing conditions. Many of the sheepmen admitted that their lands were overstocked, a practice that results in weakened ewes that produce lambs of lowered vitality. If the sheepmen would reduce their stock to the proper carrying capacity of the land and increase their personnel during the lambing season so that the newborn could be given more immediate attention, there would be fewer weakened lambs and these would have a better chance of survival.

BIRDS AND THEIR EGGS

Remains of birds and their eggs were found in 52, or 7.36 percent, of the adult raven stomachs (table 5, p. 47) and supplied 1.56 percent of the entire food (included in Other vertebrates, table 3). Egg remains occurred in 24 stomachs and in some formed a substantial part of the contents—as much as 80 percent in 1. Those in 12 of the stomachs were identified as chicken eggs; those in the other 12 were not determined. In 2 stomachs both a chick and eggshells were found. Remains of domestic chickens were noted in 18 stomachs and of birds of uncertain identity in 14. The scaled quail (*Callipepla squamata*) was identified in 3 stomachs and contributed 35, 5, and 1 percent of their contents, the 5 percent being supplied by a chick. Mourning doves (*Zenaidura macroura*) were eaten by 7 ravens and furnished as much as 33, 48, 50, 60, and 80 percent of the food of 5 of them. As 1 of the doves was eaten in August just 6 days before the dove hunting season opened and the others were consumed in September during the early part of the open season, it is possible that all 7 doves were unretrieved birds that had been killed or crippled by hunters. Passerine birds were noted in 10 stomachs. There were 6 Fringillidae (sparrows, finches), 1 of which furnished 93 percent and another 60 percent of the contents of single stomachs.

White-necked ravens are often accused of destroying the eggs and young of poultry, and other bird life as well, and the results of the stomach analyses substantiate the charge. Several farmers have told of seeing ravens closely watch a turkey during the laying period and then swoop down and eat the freshly laid egg as soon as the turkey left the nest. Two of the birds banded in the course of this study subsequently were killed because they were thought to be catching young chicks.

Merely to state that the ravens feed on poultry and their eggs without explaining the source of the food may lead to erroneous conclusions, however. Rarely have these birds been seen taking eggs from nests close to the hen house; most of the depredations are at nests out in the brush or on strawstacks or in other places away from buildings. Turkeys have the habit of trying to hide their nests, and many farmers think they will not nest unless permitted that freedom. Raven predation on eggs or young birds around the poultry yard is an action to be condemned and controlled, but similar activity at outlying nests should in a measure be condoned as it is due in part to man's carelessness. Egg fragments, too, may come from yet other sources. Ravens commonly feed along highways and around school grounds on lunch scraps that may contain eggshells, and once the writer saw a flock of ravens near Pecos, Tex., feeding on eggs that had been broken in a car wreck.

It is doubtful whether the passerine birds found in the stomachs were killed by the ravens. Most small birds are more agile than the raven and would scarcely be caught unless sick or crippled. The writer has never seen any signs of ravens being aggressive against adult birds of other species; on the contrary he has commonly seen such birds as the scissor-tailed flycatcher making life miserable for the raven.

Remains of wild birds or their eggs in the raven's food are indicative of objectionable habits only when the raven has killed young birds or has pilfered nests. When the eggs have been gleaned from deserted nests or when infertile unhatched eggs and dead birds have been fed upon, the acts must be considered of neutral significance.

REPTILES, AMPHIBIANS, AND FISHES

Reptiles, amphibians, and fishes together made up only slightly more than 1 percent of the food of the adult ravens (included in Other vertebrates, table 3), but they occurred in almost 10 percent of the stomachs. The largest quantity was taken in May, but if to the number consumed in June, the month when the adults started feeding the young, were added the number fed to the nestlings during the month, the total destroyed by the adults would be about the same as in May.

The forms identified in this lower vertebrate food are listed in table 5 (p. 47). Reptiles, including lizards, snakes, and turtles, predominated. Lizards were taken most frequently, and of the 5 genera represented, *Phrynosoma* (horn-toads) was by far the most important. Amphibians, consisting of salamanders, toads, and frogs, were noted in 15 stomachs. The single fish eaten was a small minnow, probably found dead.

The insect-destroying activities of amphibians and reptiles, of the smaller lizards particularly, make the presence of these vertebrates in the raven's diet a point in the bird's disfavor; but the quantity taken was so small that the economic significance is slight.

PLANT FOOD

Vegetable material occurred in 608, or 86 percent, of the adult stomachs and formed 50.33 percent of the total food. It was eaten in every month and formed as high as 76.69 percent of the food volume in November and 72.5 percent in August. The plants consumed most commonly and in greatest quantity were the grain sorghums, but wild fruits and corn were relished also. It is the raven's great liking for certain cultivated crops that makes it so serious a problem to the farmers. The plants noted in the stomachs are listed in systematic order in table 5 (p. 47).

GRAIN SORGHUMS

Slightly more than half the vegetable diet of the adult ravens consisted of grain sorghums. They supplied 25.66 percent of the yearly food; were eaten by 375, or 53.04 percent, of the birds; and were taken in every month except June and July. The varieties with softer kernels, such as milo, hegari, and kafir, were preferred to the harder Sumac (Red Top) sorgo.

The quantity eaten fluctuated from month to month, as is shown in table 3 and figure 7. This may be due in part to too small a series of stomachs, but it may also represent definite trends in the bird's habits that can be explained only by knowledge of conditions in the field. After the nesting season is over the ravens move into the farming areas and as soon as the grain sorghums have developed to the dough stage start eating them. This is generally in August, and in that month these grains were found in 30.77 percent of the stomachs examined and formed 2.58 percent of the food. That the volume consumed rose abruptly in September, increased in October, and reached its high in November (48.19 percent) reflects the stages of development and availability of the grain during these months. Not only does the late crop far exceed the early one in acreage, but most of it matures in November. The large quantity eaten during January may represent a loss of some grain still in the shock, but it is made up chiefly of waste grain gleaned from the fields. The decline in February and March is brought about by the small quantity of sorghums then available and by the increase of insect and mammalian food in the diet. The rise in April is due to the fact that, other foods being scarcer, many stockmen feed bundles of the grain to the cattle in the pastures and that ravens eat the part that is shelled out—which would otherwise be wasted—and pick out the undigested kernels from cow dung. The sharp drop in May is because choicer foods then become more available and tempt the birds to a more varied diet.

The losses inflicted by white-necked ravens on grain sorghums in general and on milo, hegari, and kafir in particular—because of the great acreages of these grown and the long period of their availability—are greater than on all other crops. The birds prefer the sorghums in the late dough stage but readily take ripe seed also. Maturing grain can be found from August until late November, and ripe grain is available in shocks and stacks from that time on until late spring.

In the areas of more concentrated raven populations it is not uncommon to find fields of grain sorghums that have been severely damaged by the birds, as flocks of 50 to 500 may alight in a field and inflict heavy losses if left undisturbed. Whenever the birds band together, particularly during drought years when food is scarce, they present a much greater problem than normally. Such a situation calls for continual vigilance with a shotgun and a quick harvest as soon as the grain matures. In late winter and in spring, again especially in years when drought has drastically reduced the food supply, considerable trouble is experienced with the ravens eating the grain from stacks and ricks. At such times close minding the grain or covering it is necessary.

Texas is the leading State in the production of these grains, which are grown mainly in the western half of the State in an area that coincides closely with that of heavy raven concentrations. There are large acreages of the crop in the Panhandle of Texas, too, but the ravens are relatively scarce there, principally because the plains country does not afford the brush necessary for roosting.

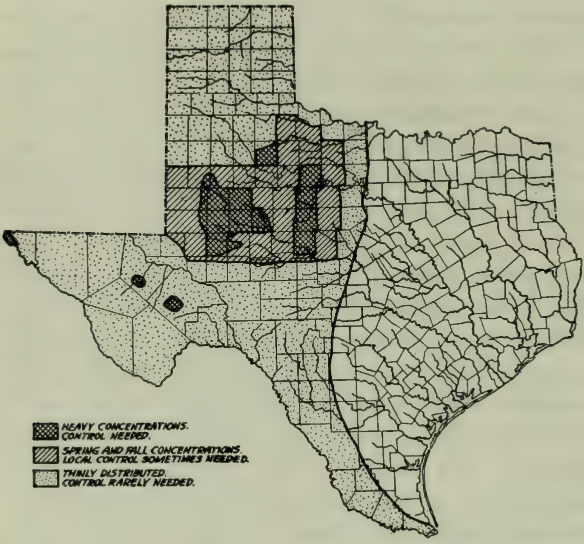
HEAVY CONCENTRATIONS. CONTROL NEEDED.
SPRING AND FALL CONCENTRATIONS. LOCAL CONTROL SOMETIMES NEEDED.
THINLY DISTRIBUTED. CONTROL RARELY NEEDED.

FIGURE 9.—Distribution of the white-necked raven in Texas, with the eastern limit indicated by the heavy line between the stippled and white areas.

The raven's distribution in Texas is shown roughly in figure 9. In the areas of heavy concentrations (cross-hatching) control activities are justified; in those of only spring and fall populations (hatching) some local control at times may be needed, but because of an abundance of choice food it is usually impracticable and frightening devices are more useful; and in the areas where the birds are scattered (stippling) control is very seldom necessary, as only small local aggregations are possible and in most instances are comprised of so few birds that the damage inflicted is slight.

There is enough migratory movement among the ravens for damage to be wholly seasonal in some parts of their range. Along the northern part of Texas adjoining Oklahoma, in extreme western Texas, and in eastern New Mexico most of the birds retire from agricultural to range lands for nesting. In August, the young birds, able by that time to fly, accompany the adults to the nearest farming areas, where they all sojourn until about November. Then they move into more southern agricultural districts for the winter, dispersing again early in March for nesting.

Other birds, particularly blackbirds and lark buntings, also feed heavily on grain sorghums, and often the ravens are blamed for the injury they do. Raven attack can easily be distinguished from that of smaller birds, however. The latter pick out the individual kernels and seldom leave any waste, whereas the ravens in an attempt to get several kernels at once eat the grain with a chopping action of the beak that results in many broken and cut kernels on the head and considerable waste on the ground. Recumbent grain heads that have been fed on by rodents and rabbits may resemble those worked on by ravens, but in such instances droppings or tracks may serve to identify the pilferer.

CORN

Corn is a minor crop in the raven territory, where, except for parts of Terry, Yoakum, and Gaines Counties, Tex., and eastern Lea County, N. Mex., it is raised only in small patches for home consumption. In the counties named it is grown on a commercial scale and so suffers proportionately greater loss from ravens.

The most frequent criticism of the ravens in relation to the corn crop is that they damage the grain while it is in the milk, or roasting-ear, stage. After they have torn open the husks and eaten some of the succulent kernels, water and spores may enter and ear rot result. This type of injury is pernicious, as consumption of only a few kernels may result in loss of an entire ear. No corn was found, however, in any of the stomachs collected during the 4 months June through September, the main roasting-ear season. This does not mean that the damage cited is mythical; rather it reflects the small quantity of corn grown in the raven territory and the fact that a very small consumption by many birds may mean severe loss locally.

Very little complaint is voiced against the raven for pulling planted corn. The explanation is threefold: (1) The patches of corn are small and widely scattered; (2) at this period the insect supply, which is preferred to corn, is bountiful; and (3) the ravens are engaged in nesting activities, largely in pastures many miles distant from the farming sections.

Corn was found in 12.16 percent of the adult raven stomachs, comprised 5.28 percent of the food, and reached its high in the monthly diet (22.07 percent) in March.

The chief source of the corn eaten in November, when it formed about a tenth of the food, was unharvested grain (fig. 10). Unless the crop is closely minded while in the field the ravens will damage it severely. The writer has seen many fields where they have removed more than 50 percent of the grain from the ears. Because the acreages of corn grown are small it is easier to keep the ravens out of this crop than out of crops grown in larger acreages.

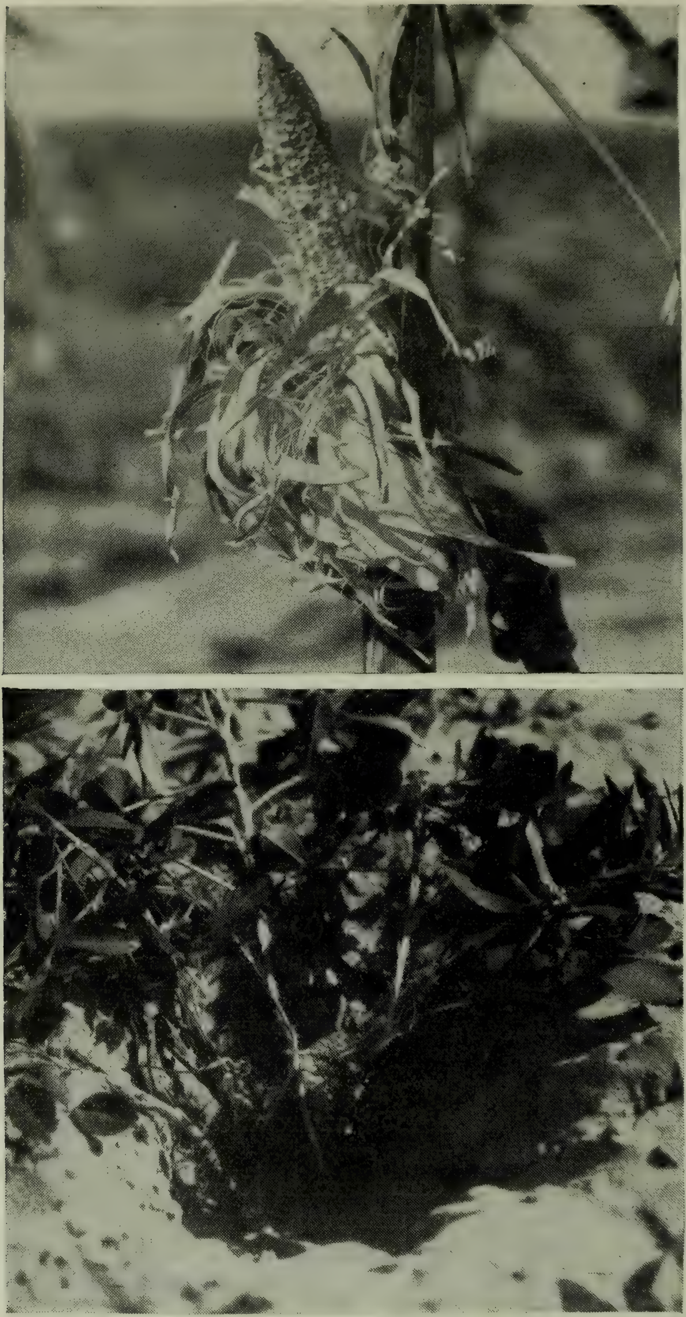

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FIGURE 10.—White-necked raven damage to crops: *Above*, to mature corn; *below*, to peanuts, showing that the nuts have been removed from the soil beneath the vine.

The mere presence of these birds in a cornfield, however, does not always prove that they are eating the grain. In September 1934 the writer flushed about 25 ravens from a cornfield in Terry County, Tex., and fully expected to find that they had done serious damage. Examination of the corn showed, however, that it was very wormy and that the worms and plant lice had practically ruined the tassels and young ears. The ravens had been tearing open the husks and eating the worms. The ears thus exposed likely would have developed rot, but this damage would have been no greater than the injury the worms would have caused.

Most of the corn eaten during late winter and early spring was gleaned from feed lots, hogpens, and poultry yards. At this time of year the available food supply is lowest and the birds forage over wide areas They are attracted to the environs of small towns and to farmyards and stock-feeding lots, and when they feed in these places corn is likely to form an important part of their diet. One series of March birds that was collected near a feeding pen had partaken freely of corn.

For the most part then the corn in the raven's food must be classed as a direct loss to man, inasmuch as most of it represents either destruction of the crop or consumption of poultry and livestock feed and very little of it indicates utilization of waste grain.

OTHER GRAINS

The other grains in the raven diet, including oats, wheat, barley and rye, were taken in small quantities in every month but July, oats more often than all the others. This food was derived mainly from harvest waste, grain distributed in rodent-control campaigns, poultry and stock feed, and dung. The greatest monthly consumption (11.15 percent), which was for August, represented mostly waste grain; and the oats contained in one small series of winter stomachs had been cooked, showing the source to have been hog or poultry feed. Relatively little complaint about the ravens eating small grains is made, however, as in the raven territory most of these mature in June when insects are so abundant as to decoy the birds away from the less palatable grain food.

OTHER CULTIVATED CROPS

Under this caption are grouped peanuts, watermelons, cantaloups, honeydew melons, tomatoes, castor-beans, sunflower seeds, and pears. These aggregated 7.27 percent of the adult annual food, with peanuts forming slightly more than 2 percent, melons a little more than 4, and the others a little less than 1.

Peanuts.—The total peanut acreage within the raven belt is not large, being confined principally to a few sandy areas in northern Taylor, southern Jones, and Eastland, Callahan, and Comanche Counties. When raven damage to peanuts occurs it is usually severe, and as the birds are adept at digging out the nuts without disturbing the vines it is often inflicted before the farmer is aware of what is happening. The birds begin to dig the nuts when they start forming in August and continue to feed on them until the crop is taken from the field, usually early in October (fig. 10).

Peanuts occurred in greatest quantities in the stomachs collected during December, January, and February, when they represented either waste from the field or livestock feed. About half those found in the February stomachs came from chicken or hog feed composed of cooked peanuts, milo, and oats. Peanuts were unimportant in the food during August, September, and October, the months when there is most trouble with the birds in this crop. This is because they are only very locally cultivated and few of the stomachs were collected in the vicinity of peanut fields.

Scaring devices are the only means by which the birds can be kept out of peanut fields (p. 52), as the abundance of food at the time damage is done makes the use of traps or poison very ineffective. It is desirable and practicable to stack the peanuts around a pole with the nuts to the center to reduce losses during the curing period and then to speedily remove the whole crop from the field as soon as it is cured.

Melons.—Evidences of watermelons and cantaloups were found in 115, or about one-sixth, of the stomachs examined. Seeds chiefly were noted; rarely was any flesh discernible. Melons were eaten to a greater extent following rather than during the main melon season. During July, August, and September the melons are at their best, but of the birds examined only 3 had eaten them in August and 8 in September. The probable reason for this is that the farmers of Texas are very fond of their watermelons and cantaloups and make special efforts to keep the birds away from them until their own desires are satisfied or the main part of the crop has been harvested. When prices drop or when most of the good melons have been eaten, the strict guard over the crop is relaxed and the birds start feeding in the fields in large numbers. During October and November, ravens could almost invariably be found in or near unprotected melon fields, and many of the stomachs representing those months were collected from such fields.

The real loss from raven damage to melons is not in the bulk actually consumed but in the large number of melons pecked and left with holes through which bacteria and fungi enter and ruin the fruit. If the birds would confine their feeding to one melon until it was completely eaten before pecking into others, less fruit would be injured and the loss would not be great; but by their procedure in a very short time they often cause a very great many melons to spoil. It is extremely disappointing to a farmer and his family to go through the hot, dry summer anticipating melon feasts, only to find that the ravens have been in the patches first. It is this disappointment more than the economic loss that creates the antiraven feeling among farmers, many of whom have told the writer that they would rather lose 5 or 10 acres of grain sorghums than their little melon patch.

Where melons are grown on a commercial scale, if the crop were not protected the loss per acre from ravens would undoubtedly exceed that resulting from all other raven depredations combined.

Prevention of damage rather than control of the birds is suggested during the melon season. This can best be accomplished by the use of frightening devices (discussed on pp. 52 and 53) and by having the home melon patch close to the house so that it may be better guarded. Protection is often afforded, too, by sprinkling the melons with lime or whitewashing their tops or by covering them with sacks when they are about full grown. It is appreciated that the type of soil near the farmhouse is not always favorable to melon production and that the ravens may visit the patch while the family is away; nevertheless, planting near the house is one of the most effective ways of getting the melons through the season without undue loss.

The wild "pie melon," or citrus melon, is common in parts of the raven territory and is eaten by the raven as well as by rabbits, rodents, and cattle. The birds' consumption of this food can hardly be considered detrimental, as the melons have little economic value, even though a few are used for preserves.

WILD FRUITS

Wild fruits were important in the diet, as they formed 7 percent of the yearly food, were eaten by 19.66 percent of the birds, and were taken in every month. In January and November they supplied only a small part of the food, less than 1 percent, but in the other months were eaten in larger quantities, furnishing more than a tenth of the food in December, about a fourth in May, and nearly half in July and August (table 3; fig. 7). Such a high consumption of wild fruits during the latter 2 months naturally helps keep the birds out of the watermelons and early grain sorghums, which are maturing at that time.

The species identified numbered 22. The pulp and seeds of "cactus apples," or pricklypears (*Opuntia*), which were eaten more often than any other wild fruit, formed their greatest bulk in the diet in July and August. Practically every raven shot in those months had fed on these deep red fruits, as evidenced by red stains on their feet and vents. Fruit of buckthorn (*Condalia*) was important in May and June, and hackberry (*Celtis*) was the dominant wild fruit food in the fall and winter months. The remaining species were eaten so infrequently that little significance can be attached to their presence in the diet.

MISCELLANEOUS SEEDS

Seeds of weeds, grasses, and other plants formed a minor part of the adult ravens' food but were found in stomachs collected in every month except June. They embraced 41 genera, of which 9 were wild grasses and 1 a sedge. Seeds of the unicornplant (*Martynia louisiana*) and sunflower (*Helianthus*) predominated. Many of the smaller seeds were no doubt taken accidentally with other foods. The effect these birds have on the control of weeds is slight and does not contribute much to their credit.

MISCELLANEOUS ITEMS

Cheese occured in a single stomach and paper and rubber bands in two and three stomachs, respectively. The cheese and paper doubtless were taken from luncheon debris along the highway. The elastic bands merely illustrate the curious nature of these ravens. Glass marbles and rubber bands were found among the pellets at roosts on several occasions.

FOOD OF NESTLINGS

Inasmuch as each pair of ravens produces an average of four young annually, the nature of the food consumed by the nestlings is of importance in an economic appraisal of the species. Young in nests can be found from late May until the latter part of July, so that their food habits are of consquence over a 2-month period. The nestlings are fed by the parents for 3 or 4 weeks, after which they forage for themselves.

The interpretation of items in the diet of nestlings is somewhat different from that of like items in the food of adults. For instance, mouse remains in the stomach of an adult usually indicate an entire individual eaten but in the stomach of a nestling may mean only part of a mouse consumed, as a single victim often is divided among a brood and so at times may account for as many as six occurrences.

In all, 120 nestling stomachs were examined, 8 of which were collected during May and 112 in June. It is regretted that no stomachs were available for July, but doubtless the food for that month would not have differed much from that for June. Probably the only item that would have shown an increase is wild fruits. The volumetric and occurence percentages of the principal food groups are presented in order of volumetric importance in table 4, and the volumetric food percentages are illustrated graphically in figure 11. The food items are listed systematically in table 5 (p. 47).

The thin and delicate nature of the nestling's digestive tract makes it imperative that the young bird be fed easily digested foods almost exclusively; thus it is not surprising that animal matter formed about 99 percent and vegetable matter only a little more than 1 percent of the food of the 120 nestlings. The stomachs of even the older nestlings were thinner walled than those of adults and were also larger and so of greater capacity.

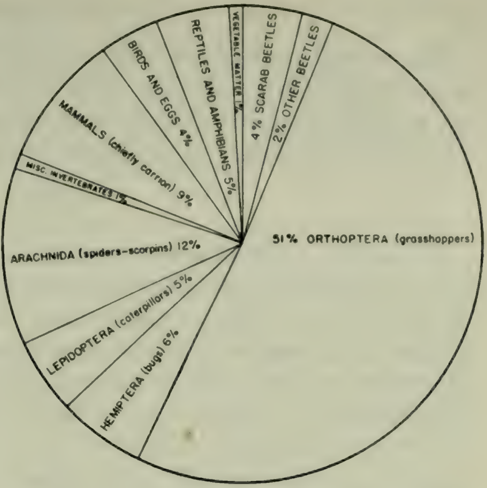

FIGURE 11.—Food of 120 nestling white-necked ravens. Each sector represents the volumetric percentage of the food named. Table 4 presents both volume and occurrence percentages.

TABLE 4.—*Volume and occurrence percentages of principal food groups in the diet of 120 nestling white-necked ravens in May and June*

[Volume percentages are presented graphically in fig. 11]

Food group	Percentage	
	Volume	Occurrence
ANIMAL FOOD		
Insects:		
Grasshoppers and allies (Orthoptera)	51. 21	99. 17
Beetles and weevils (Coleoptera):		
Scarab beetles (Scarabaeidae)	3. 98	49. 17
Ground beetles (Carabidae)	1. 52	32. 50
Darkling beetles (Tenebrionidae)	. 45	3. 33
Weevils (Curculionidae)	. 03	10. 83
Other beetles [1]	. 18	20. 83
Total Coleoptera	6. 16	
Bugs (Hemiptera)	5. 83	58. 33
Caterpillars (Lepidoptera)	4.74	38. 33
Other insects (Diptera and Hymenoptera)	. 28	15. 83
Total insects	68. 22	
Spiders and allies (Arachnida)	11. 59	75. 00
Mammals, chiefly carrion	8. 82	36. 67
Reptiles and amphibians	5. 52	20. 83
Birds and their eggs	3. 78	15. 83
Miscellaneous invertebrates (centipedes, millepedes, and snails)	. 75	12. 50
Total animal food	98. 68	
PLANT FOOD		
Vegetable fibers, milo, weed seeds, and wild fruit	1. 32	15. 83

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[1] Cicindelidae, Silphidae, Histeridae, Elateridae, Buprestidae, Phalacridae, Cerambycidae, and Chrysomelidae.

ANIMAL FOOD

The animal part of the nestling food was composed of a variety of forms from arthropods and snails to reptiles, birds, and mammals; but most of it consisted of insects, which contributed more than two-thirds (68.22 percent) of the entire food.

INSECTS

Orthoptera.—Grasshoppers and their allies supplied more than half (51.21 percent) the nestling diet and were present in 99.17 percent of the stomachs. Mantids (Mantidae) were found in 5 stomachs and crickets (Gryllidae and Stenopelmatinae) in 3, but practically all the orthopterous food was composed of grasshoppers of the families Acrididae and Tettigoniidae. These made up 50 percent or more of the contents in 69 stomachs and 90 percent or more in 12.

In all, the remains of 1,803 grasshoppers were found in the 120 nestling stomachs, an average of 15 a stomach. The average number eaten by each adult in June was 12. Considering the raven brood to be 4, then at each feeding period during June each nesting pair of ravens destroys at least 84 grasshoppers. As the adult stomachs usually are filled and emptied twice during the day and the nestling stomachs, being larger, undoubtedly oftener, to compute the number of grasshoppers destroyed by a nesting pair daily the 84 may be doubled at least, giving 168—a conservative figure.

The economic importance of these insects in the June diet can better be shown by some hypothetical figures based on counts made at a few of the raven roosts known to be in existence, the population of which was conservatively estimated at 106,400 birds. Assuming an equal distribution of sexes and 80 percent of the birds breeding, there would be 42,560 pairs of ravens each raising an average of 4 young. Applying the above figure of 168, the total number of grasshoppers eaten daily during the month would be 7,150,080.

The number of grasshoppers found in the individual stomachs of a brood of nestlings gives indication that the young are afforded nearly uniform care, as in numerous broods each nestling had received the same or nearly the same number of these insects. It makes one wonder whether ravens can count or can recognize the young individually.

Coleoptera.—Beetles (6.16 percent) ranked second in volume in the insect food of the nestlings as they did in the adult diet. Scarabs (3.98 percent) were the most important; and of these May beetles (*Phyllophaga*) furnished the greatest percentage and a limited variety of both plant-feeding and coprophagous forms made up the remainder. Next in importance were the carabids (1.52 percent), both plant-feeding and predaceous species. Other beetles, representing at least

10 families of varying economic worth, constituted an unimportant part of the diet, even in the aggregate (0.66 percent).

Hemiptera.—The true bugs were the next most important order (5.83 percent) in the insect diet. The families represented most frequently were the Pentatomidae (stinkbugs) and Cicadidae (harvest flies). Apparently stinkbugs, though obnoxious to the human sense of smell, are not particularly distasteful to ravens.

Lepidoptera.—Moths and caterpillars (4.74 percent) were found in 46 nestling stomachs but in only 6 contributed 25 percent or more of the food, the largest percentage being 58. The order was represented primarily by larval forms (caterpillars), which occurred in a third of the stomachs; but a few adults and one cocoon were noted. The larvae were not identified beyond the order, but undoubtedly a good many were Sphingidae (sphinx or hummingbird moths) and Phalaenidae (cutworms).

Other insects.—All the other insects eaten by the nestlings made up only 0.28 percent of the diet. They comprised undetermined forms, noted in one stomach, and three orders: Hymenoptera, represented by a wasp (Vespidae), a spider wasp (Psammocharidae), and a bee (Panurgidae); Diptera, consisting of a midge (*Cricotopus*), an ox warble (*Cuterebra*), and Muscidae of the species *Chrysomia;* and Mallophaga (bird lice).

ARACHNIDA

Spiders and their relatives are important sources of food for the nestlings and because of their soft bodies are especially suitable for the newly hatched birds. These eight-legged animals formed 11.59 percent of the nestling diet and were found in three-fourths of the stomachs. The adults during the same period that the nestling stomachs represent (May and June) obtained less than 3 percent of their diet from this source. Spiders formed the greatest bulk of the arachnid food and occurred more frequently than other members of the group, but as their soft bodies made identification difficult only a few families were recognized. The number of spiders consumed by individual nestlings was small, usually from one to three. Inasmuch as the Arachnida are largely insect predators, their presence in the raven's diet can only be to the bird's discredit.

OTHER INVERTEBRATES

All other invertebrates eaten, including centipedes, millepedes, and snails, together formed only 0.75 percent of the nestling food.

MAMMALS, CHIEFLY CARRION

Mammal items were found in a few more than a third of the nestling stomachs and made up 8.82 percent of the food. Such forms of carrion of larger animals as bone, hair, and flesh were found in 7 stomachs; and remains of rabbits, probably also of carrion origin, in 10. Pocket mice (*Perognathus*) remains were noted in 27 stomachs; but this figure does not represent that many mice killed, because 1 individual was usually divided among a brood. Remains of a white-footed mouse (*Peromyscus*) and of a harvest mouse (*Reithrodontomys*) were found in a single stomach each.

REPTILES AND AMPHIBIANS

The reptiles and amphibians (5.52 percent) eaten by the young ravens consisted mostly of lizards, although toads, a box turtle, and the burrowing snake *Tantilla nigriceps* were taken by a few nestlings.

BIRDS AMD THEIR EGGS

Birds, including domestic poultry, and their eggs formed 3.78 percent of the young ravens' food. In all, 13 stomachs contained fragments of eggshells, including those of domestic chicken, prairie chicken, a mourning dove (possibly), and other birds not identified. The prairie chicken eggs were eaten in Oklahoma in the heart of an area well suited to these game birds, but the person who collected the ravens involved did not feel that the ravens were a serious menace to the prairie chickens.[4]

PLANT FOOD

The vegetable part of the nestlings' food was composed largely of plant fibers ingested incidentally with such foods as grasshoppers and spiders, but there was also at least one occurrence of each of the following fruits: Buckthorn (*Condalia*), cherry (*Prunus*), blackberry (*Rubus*), and mulberry (*Morus*).

SUMMARY OF FOOD HABITS

Laboratory examinations of 707 adult and 120 nestling stomachs of the white-necked raven and field examinations covering almost every month show the bird to be an omnivorous and resourceful feeder and demonstrate that its seasonal food is governed largely by the factor of availability. In all, 288 different items (214 of animal and 74 of vegetable origin) were identified (table 5, p. 47), and if all material found in the stomachs could have been specifically identified no doubt the number would have been increased. Although the animal items far outnumbered the vegetable, the total volumes of the two kinds of food were about equal in the adult diet. The nestlings, though, were almost entirely carnivorous.

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[4] Davison, Verne, and McAtee, Waldo Lee: Report on the Arnett, Oklahoma, experimental quail and prairie chicken management project. U. S. Bur. Biol. Survey Wildlife Res. and Mgt. Leaflet BS-39, 6 pp. [Processed.]

Insects as a class contributed the greatest bulk of food, as they supplied nearly a third of the adult and more than two-thirds of the nestling diet. The injurious forms eaten outnumbered the beneficial.

Grasshoppers (Orthoptera) were consumed in greater quantity than any other insect group. They made up more than half (51.21 percent) of the nestling and about an eighth (12.56 percent) of the adult food, although in the latter they reached a high of 60.32 percent in June. The raven's untiring war on grasshopper pests during the warmer months appreciably offsets the damage the bird inflicts at other seasons.

Beetles (Coleoptera) were second in volume in the insect diet of both adults and young. For the adults, weevils ranked first in this group and scarabs second; for the nestlings, scarabs first and ground beetles next. The other coleopteran families represented in the food furnished such small percentages that they are of little significance in the bird's economic status. As weevils and scarabs are among the most injurious beetles, the raven's consumption of them in large quantities is definitely a point in the bird's favor.

Lepidoptera ranked third in quantity in the insect diet of the adults and fourth in that of the nestlings. Those taken were almost all injurious forms, such as cutworms, sphingid larvae, and adults of a *Datana* moth. This part of the diet is without question entirely to the bird's credit.

Hemipterous forms of insects, consumed in small quantities, were of more importance to the nestlings than to the adults. They consisted largely of stinkbugs and leafhoppers. Again this part of the insect diet refects beneficial activities on the part of the raven.

Several other insect orders were represented in the food, but in quantities and numbers so small that little economic significance can be attributed to their consumption.

Spiders were unimportant in the adult food but formed more than a tenth of that of the nestlings, their soft, easily digested bodies being especially suitable for the thin and delicate digestive tracts of the young birds. The fact that spiders are generally considered beneficial places this item of the diet against the raven, but the total quantity consumed was so small that it has little effect on the bird's economic status.

Earthworms, myriapods, and snails were eaten so sparingly that their presence in the diet is of no significance.

Mammalian food was important in the diet, ranking second in the animal food of the adults and third in quantity in the nestling food. Most of it consisted of carrion, which was obtained chiefly from carcasses of horses, cows, sheep, and rabbits. The presence of dead animals annually attracts many ravens to the sheep country, where the birds occasionally prey on weak lambs and ewes. This damage, while pernicious and highly criticized, is somewhat compensated for by the raven's destruction of carrion on the same range. The carrion-eating habit is commendable also in that it reduces breeding places for flies and aids in general sanitation of the range. Small rodents were eaten sparingly. Their presence in the diet indicates beneficial predation on the part of the raven.

Birds, including domestic poultry, and their eggs were found in but a small proportion of the stomachs. It is an established fact, though, that ravens will pilfer nests and destroy young of other birds when these are not well guarded or concealed. It is questionable whether they ever destroy normal adult birds, because most of these are fully able to protect themselves against the ravens. Poultry losses from ravens, a large percentage of which are inflicted at nests and on young in areas distant from the farmyard, can largely be prevented by providing suitable enclosed nesting facilities.

Reptiles and amphibians formed about 6 percent of the food of the nestlings but only slighty more than 2 percent of that of the adults. The greatest bulk of this food was lizards, which were eaten mainly in summer. The insect-destroying activities of reptiles and amphibians make their presence in the diet a point of some discredit to the raven.

Cultivated crops offer the greatest supply of food to the white-necked ravens and so are somewhat responsible for the sporadic concentrations of these birds. Grain sorghums were the most im-important plant food item found in the stomachs examined and made up more than a fourth of the adult birds' subsistence. The varieties with softer kernels were preferred; and all kinds were eaten more readily during the late dough stage, although the mature seeds also were relished. Because of the large acreages of grain sorghums grown and the concentrations of ravens attracted to them, raven damage to these grains is greater than to any other crop. If undue losses are to be avoided, close minding of the sorghums during maturing and harvesting is usually essential. Actual control of the ravens or reduction in their numbers during the crop-growing season is impracticable because of the bounteous food supply available at that time of year. Cultivated crops of less importance that are attacked by the raven and may be severely damaged locally are corn, peanuts, melons, tomatoes, castor-beans, sunflower seeds, and pears. The acreages involved are so small, though, that the economic significance is not great. Vigilant guarding with firearms and frightening devices must be resorted to where the ravens are numerous. Wheat, oats, barley, and rye are minor crops in the raven territory and were not fed on excessively by the birds examined.

Wild fruits were consumed in large quantities during the summer and early fall and therefore played an important part in helping reduce the amount of feeding done in cultivated crops at that time.

ITEMS IDENTIFIED IN THE STOMACHS

Table 5 lists all the items found in the 827 white-necked raven stomachs examined. The arrangement of the foods identified is systematic through families and alphabetic for genera and species.

TABLE 5.—*Items identified in the stomachs of 827 white-necked ravens (707 adults and 120 nestlings) and number of stomachs in which they occurred*

ANIMAL FOOD

Food item	Number of stomachs in which found	
	Adult	Nestling
OLIGOCHAETA		
Earthworm	1	------
ARACHNOIDEA: ARACHNIDA		
Scorpionida:		
Centruridae:		
Centrurus carolinianus	1	4
Species undetermined	5	10
Undetermined	4	24
Solpugida:		
Solpugidae:		
Eremobates sp	1	
Undetermined	28	2
Phalangiida	7	15
Araneae:		
Lycosidae	2	13
Salticidae		2
Undetermined	49	37
Acarina:		
Parasitidae:		
Uropoda sp	------	1
MYRIAPODA		
Diplopoda	20	6
Chilopoda:		
Scolopendra sp	------	1
Undetermined	5	------
INSECTA		
Orthoptera:		
Mantidae:		
Stagmomantis sp	76	5
Phasmidae	17	------
Tettigoniidae:		
Eremopedes sp		1
Neoconocephalus sp	1	------
Undetermined	21	75
Stenopelmatinae	1	1
Gryllidae:		
Anurogryllus sp	1	
Undetermined	8	2
Acrididae:		
Brachystola sp	3	------
Chortophaga sp	------	1
Hippiscus sp	1	5
Melanoplus sp	7	6
Orphuella sp		1
Undetermined	326	118
Undetermined	3	
Isoptera:		
Termitidae:		
Amitermes tubiformes	1	
Undetermined	10	
INSECTA—continued		
Neuroptera:		
Chrysopidae:		
Chrysopa sp	1	------
Odonata: Zygoptera	1	------
Mallophaga	------	1
Hemiptera:		
Cydnidae:		
Aethus sp	1	------
Galgupha sp	1	1
Pentatomidae:		
Aelia americana	2	------
Banasa sp	1	------
Brochymenia sp	8	------
Coenus delius	1	------
Euschistus sp	3	------
Hymenarcys nervosa	2	------
Species undetermined	17	------
Nezara sp	22	------
Peribalus limbolarius	1	------
Podisus acutissimus	1	------
Solubea pugnax	1	------
Thyanta sp	3	------
Undetermined	49	29
Coreidae:		
Anasa tristis	1	------
Archimerus sp	9	------
Aufeis impressicollis	4	------
Chariesterus sp	1	------
Coriscus sp	1	------
Harmostes sp	2	------
Lygaeidae:		
Geocoris sp	2	------
Lygaeus kalmii	1	------
Reduviidae:		
Rocconota sp	1	------
Sinea confusa	3	------
Species undetermined	2	------
Undetermined	4	1
Nabidae:		
Nabis sp	1	------
Miridae	1	------
Cicadidae:		
Cacama sp	3	------
Tibicen sp	1	------
Undetermined	3	32
Membracidae:		
Ceresa sp	1	------
Stictocephala festina	29	------
Cicadellidae	1	
Coccidae	1	
Undetermined	9	1

TABLE 5.—*Items identified in the stomachs of 827 white-necked ravens (707 adults and 120 nestlings) and number of stomachs in which they occurred*—Continued

ANIMAL FOOD

Food item	Number of stomachs in which found	
	Adult	Nestling
INSECTA—continued		
Coleoptera:		
Cicindelidae:		
Cicindela sp	8	3
Carabidae:		
Amara sp	1	------
Anaferonia sp	4	1
Anisotarsus sp	------	5
Calosoma lugubre	3	3
triste	1	------
Species undetermined	38	8
Chlaenius orbus	1	------
tomentosus	------	2
Cratacanthus dubius	1	------
Species undetermined	1	------
Evarthrus sp	1	1
Geopinus incrassatus	3	------
Harpalus gravis	1	------
pennsylvanicus	1	------
Species undetermined	8	1
Nothopus sp	1	2
Pasimachus depressus	1	------
Species undetermined	10	4
Philophuga viridicollis	1	------
Species undetermined	2	------
Piosoma setosa	3	------
Poecilus sp	1	------
Pterostichus sp	1	------
Selenophorus sp	4	------
Triplectrus rusticus	1	------
Hydrophilidae:		
Sphaeridium scarabaeoides	1	------
Silphidae:		
Necrophorus sp	------	1
Staphylinidae	3	------
Histeridae	4	1
Anthicidae:		
Notoxus sp	1	------
Cebrionidae:		
Scaptolenus estriatus	1	------
Elateridae:		
Aeolus dorsalis	1	------
Species undetermined	1	------
Lacon rectangularis	3	------
Undetermined	6	2
Buprestidae:		
Acmaeodera sp	4	------
Chrysobothris sp	1	1
Hippomelas obliterata	1	------
Undetermined	10	3
Dermestidae:		
Dermestes sp	8	------
Undetermined	2	------
Nitidulidae:		
Pallodes silaceus	1	------
Stelidota sp	1	------
Phalacridae	------	1
Tenebrionidae:		
Astrotus sp	4	------
Bothrotes canaliculatus	6	------
Species undetermined	16	------
Eleodes tricostata	2	------
Species undetermined	11	------
Undetermined	------	4
Scarabaeidae:		
Aphodius sp	4	------
Bolbocerosoma sp	4	19
Canthon laevis	10	1
praticola	3	------
puncticollis	3	------
Species undetermined	30	14
INSECTA—continued		
Coleoptera—Continued.		
Scarabaeidae—Continued.		
Cotinis texana	1	------
Species undetermined	1	------
Cremastocheilus sp	1	------
Diplotaxis sp	2	------
Euphoria kernii	4	------
Ligyrus gibbosus	3	------
Species undetermined	4	------
Phanaeus vindex	10	6
Phyllophaga cribrosa	34	4
lanceolata	9	2
Species undetermined	54	17
Rhysseumus sp	1	------
Cerambycidae:		
Prionus sp	------	1
Sphaenothecus suturalis	1	------
Undetermined	4	1
Crysomelidae:		
Chrysomela sp	------	1
Cryptocephalus sp	------	1
Gratiana pallidula	2	------
Lema trilineata	1	------
Metachroma quercatum	------	1
Monoxia sp	1	------
Nodonota sp	8	------
Pachybrachys sp	------	2
Phyllotreta sp	1	------
Undetermined	4	3
Curculionidae:		
Cleonus sp	35	1
Dichoxenus setiger	1	------
Eupagoderes decipiens	2	------
speciosus	1	------
Species undetermined	72	------
Graphorhinus vadosus	2	------
Lixus sp	3	1
Ophryastes latirostris	5	------
tuberosus	4	------
vittatus	12	------
Species undetermined	193	------
Otidocephalus sp	1	------
Pantomorus tesselatus pallidus	------	2
Species undetermined	1	------
Peritaxia perforata	------	1
Sphenophorus sp	9	------
Tanymecus sp	1	------
Thecesturnus humeralis	7	------
Species undetermined	36	------
Tyloderma sp	1	------
Undetermined	25	9
Lepidoptera:		
Psychidae	1	------
Geometridae	3	------
Sphingidae	6	1
Notodontidae:		
Datana sp	22	------
Phalaenidae:		
Chorizagrotis inconcinna	1	------
Undetermined	94	3
Hesperiidae	1	------
Undetermined	77	45
Diptera:		
Chironomidae:		
Cricotopus sp	------	1
Tabanidae	1	------
Therevidae	1	------
Asilidae:		
Asilus sp	1	------

TABLE 5.—*Items identified in the stomachs of 827 white-necked ravens (707 adults and 120 nestlings) and number of stomachs in which they occurred*—Continued

ANIMAL FOOD

Food item	Number of stomachs in which found	
	Adult	Nestling
INSECTA—continued		
Diptera—Continued.		
Asilidae—Continued.		
Undetermined	2	------
Oestridae	1	
Cuterebridae:		
Cuterebra sp	------	2
Tachinidae	1	------
Sarcophagidae	30	------
Muscidae:		
Chrysomia macellaria	1	1
Species undetermined	------	1
Musca domestica	1	------
Stomoxys calcitrans	1	------
Undetermined	2	------
Chloripidae:		
Elachiptera sp	1	------
Hymenoptera:		
Braconidae:		
Chelonus sp	1	------
Ichneumonidae:		
Ichneumon sp	2	------
Ophion sp	1	------
Chalcididae:		
Brachymeria ovata	5	------
Species undetermined	12	------
Psammocharidae	1	1
Tiphiidae:		
Elis sp	1	------
Tiphia sp	1	------
Scoliidae	1	------
Formicidae:		
Camponotus sp	8	------
Formica sp	1	------
Lasius niger	1	------
Species undetermined	------	3
Leptothorax sp	1	3
Monomorium sp	1	1
Pogonomyrmex sp	4	------
Solenopsis sp	1	8
Undetermined	36	9
Vespidae:		
Polistes sp	2	1
Sphecidae:		
Bembex sp	2	------
Cerceris sp	1	------
Andrenidae:		
Andrena sp	2	------
Halictus sp	2	------
Melissodes sp	2	------
Panurgidae	--	1
Bombidae:		
Bremus sp	2	------
Undetermined	53	5
Undetermined Insecta	6	1
GASTROPODA		
Undetermined fragments	6	11
PISCES		
Cyprinidae	1	------
AMPHIBIA		
Caudata	2	------
Salienta:		
Bufo sp	2	2
Rana sp	4	------
Undetermined	4	------
Undetermined Amphibia	3	------
REPTILIA		
Squamata:		
Iguanidae:		
Anolis sp	1	------
Crotaphytus wislizenii	1	------
Species undetermined	1	------
Holbrookia sp	1	2
Phrynosoma cornutum	5	---
Sceloporus undulatus thayerii	------	1
Species undetermined	5	15
Undetermined	29	3
Colubridae:		
Elaphe sp	1	------
Tantilla nigriceps	1	3
Undetermined	5	------
Undetermined	1	------
Testudinata:		
Testudinidae:		
Terrapene ornata	------	2
Undetermined Reptilia	2	------
AVES		
Galliformes:		
Tetraonidae:		
Tympanuchus pallidicinctus	------	4
Perdicidae:		
Callipepla squamata	3	------
Phasianidae:		
Gallus sp. (domestic fowl)	18	2
Undetermined	------	3
Columbiformes:		
Columbidae:		
Zenaidura macroura	7	2
Undetermined	------	2
Passeriformes:		
Turdidae:		
Turdus migratorious	1	------
Icteridae:		
Icterus bullocki	1	------
Fringillidae:		
Callomospiza melanocorys	1	------
Pooecetes sp	1	------
Spizella sp	1	------
Undetermined	3	------
Undetermined	2	------
Underermined Aves	14	13
MAMMALIA		
Carnivora:		
Mustelidae:		
Mephitis sp	1	------
Canidae:		
Canis familiaris (dog, carrion)	1	------
Rodentia:		
Sciuridae:		
Citellus mexicanus	1	------
Species undetermined	2	----
Cynomys ludovicianus	2	------
Heteromyidae:		
Perognathus flavus	1	------
hispidus	------	4
Species undetermined	15	23
Dipodomys ordii	2	------
Cricetidae:		
Neotoma sp	3	------
Peromyscus sp	6	1
Reithrodontomys sp		1
Simodon hispidus	3	------
Undetermined	5	------
Undetermined	6	2

TABLE 5.—*Items identified in the stomachs of 827 white-necked ravens (707 adults and 120 nestlings) and number of stomachs in which they occurred*—Continued

ANIMAL FOOD

Food item	Number of stomachs in which found	
	Adult	Nestling
MAMMALIA—continued		
Lagomorpha:		
Leporidae:		
Lepus californicus	2	4
Sylvilagus floridanus	1	-------
Species undetermined	10	1
Undetermined	112	5
Artiodactyla:		
Bovidae:		
Bos sp. (cow, carrion)	5	1
Ovis sp. (sheep, carrion)	23	1
MAMMALIA—continued		
Artiodactyla—Continued.		
Bovidae—Continued.		
Undetermined	4	-------
Undetermined	1	-------
Perissodactyla:		
Equidae:		
Equus sp. (horse, carrion)	2	
Unidentified carrion	72	2
Undetermined Mammalia	34	4

PLANT FOOD[1]

Food item	Number of stomachs in which found	
	Adult	Nestling
Pinaceae:		
Pinus edulis	1	-------
Ephedraceae:		
Ephedra sp	16	-------
Gramineae:		
Avena sp. (cultivated oats)	50	-------
Buchloe dactyloides	11	-------
Cenchrus sp	2	-------
Eriochloa sp	2	-------
Festuca octoflora	1	5
Species undetermined	-------	2
Hordeum sp. (cultivated barley)	10	-------
Panicum fasciculatum	1	-------
Species undetermined	1	1
Paspalum sp	1	3
Secale sp	3	-------
Setaria spp	8	-------
Sorghum halepense	1	-------
vulgare (milo; kafir; hegari; Sumac, or Red Top, sorgo)	375	1
Triticum sp. (cultivated wheat)	27	-------
Zea mays (cultivated corn)	86	-------
Cyperaceae:		
Cyperus sp	2	-------
Liliaceae:		
Smilax sp	5	-------
Fagaceae:		
Quercus sp	1	-------
Ulmaceae:		
Celtis reticulata	21	-------
Species undetermined	4	-------
Moraceae:		
Morus rubra	1	4
Polygoniaceae:		
Polygonum sp	-------	1
Chenopodiaceae:		
Atriplex sp	1	-------
Undetermined	1	-------
Amaranthaceae:		
Amaranthus sp	8	1
Aizoaceae:		
Mollugo verticillata	2	-------
Menispermaceae:		
Cocculus carolinus	4	-------
Berberidaceae:		
Berberis trifoliata	4	-------
Species undetermined	2	-------
Papaveraceae:		
Argemone sp	1	-------
Resedaceae:		
Reseda sp	1	-------
Rosaceae:		
Prunus sp		1
Pyrus sp	1	
Rubus sp	2	1
Leguminosae:		
Acacia sp	1	-------
Arachis hypogaea (cultivated peanuts	26	-------
Prosopis glandulosa	1	-------
Geraniaceae:		
Erodium sp	1	2
Geranium sp	1	-------
Zygophyllaceae:		
Kallstroemia hirsutissima	2	-------
Species undermined	5	-------
Koeberlinaceae:		
Koeberlinia spinosa	4	-------
Euphorbiaceae:		
Croton sp	3	-------
Euphorbia sp	1	-------
Phyllanthus polygonoides	1	-------
Ricinus sp	2	-------
Anacardiaceae:		
Rhus canadensis	-------	2
Species undetermined	5	-------
Sapindaceae:		
Sapindus drummondii	3	-------
Rhamnaceae:		
Condalia obovata	10	1
Species undetermined	20	-------
Vitaceae:		
Vitis sp	2	-------
Malvaceae:		
Malva sp	6	-------
Malvastrum sp	1	-------
Cactaceae:		
Echinocereus sp	1	-------
Mammillaria missouriensis	1	-------
Opuntia engelmannii	26	-------
Onagraceae:		
Gaura sp	1	-------
Umbelliferae:		
Carum carvi	3	-------
Cicuta sp	1	-------
Cornaceae:		
Cornus sp	11	-------
Sapotaceae:		
Bumelia lanuginosa	2	-------
Species undetermined	1	-------
Boraginaceae:		
Lithospermum sp	-------	7
Verbenaceae:		
Verbena (*bipinnatifida?*)	1	-------
Labiatae	1	-------
Solanaceae:		
Lycium sp	33	-------
Lycopersicon esculentum (tomato)	4	

See footnote at end of table.

TABLE 5.—*Items identified in the stomachs of 827 white-necked ravens (707 adults and 120 nestlings) and number of stomachs in which they occurred*—Continued

PLANT FOOD[1]—Continued

Food item	Number of stomachs in which found		Food item	Number of stomachs in which found	
	Adult	Nestling		Adult	Nestling
Solanaceae—Continued.			Cucurbitaceae—Continued.		
Solanum rostratum	1		*Cucumis melo* (cantaloup, honeydew)	81	---
tuberosum (potato peeling)	1		Species undetermined (wild gourd)	5	---
Species undetermined	1		*Ibervillea* sp	5	---
Martyniaceae:			Compositae:		
Martynia fragrans	1		*Ambrosia elatior*	1	---
louisiania	28		Species undetermined	4	---
Species undetermined	5		*Helianthus* sp	25	---
Plantaginaceae:			*Verbesina* sp	1	---
Plantago sp	3		Undetermined	3	---
Rubiaceae:					
Diodia teres	1				
Cucurbitaceae:					
Citrullus vulgaris ("pie melon," watermelon)	38				

MISCELLANEOUS ITEMS

Food item	Adult	Nestling	Food item	Adult	Nestling
Cheese	1	---	Rubber band	3	---
Paper	2	---			

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[1] In general, nomenclature and systematic arrangement of plants is according to Cory, V. L., and Parks, H. B.: Catalogue of the flora of Texas. Texas Agr. Expt. Sta. Bull. 550, 130 pp. 1937.

ECONOMIC STATUS

It is extremely difficult to arrive at a generally applicable verdict with respect to a bird with such varied habits and such an adaptable nature as the white-necked raven. The occurrence of ravens in large numbers makes them potentially capable of doing either severe damage or much good, and during the season their habits may vary from one extreme to the other. If the birds were evenly distributed throughout the year and did not congregate they probably would be more beneficial than detrimental. In judging the economic status of the ravens examined in this study their yearly food habits may be segregated roughly into beneficial, 37 percent; detrimental, 33 percent; and of neutral significance, 30 percent.

Under the varying conditions that exist in the field, however, the status of the ravens will have to be determined locally and seasonally and the birds dealt with accordingly. Where the birds can be kept out of the cultivated crops without too much expense, the farmer will reap considerable benefit from their insect-eating habits and the rancher from their consumption of both insects and carrion; but where large raven concentrations occur during fall and winter and cause heavy crop losses, it is justifiable or even necessary to reduce their numbers by some method of control (p. 53).

CROP PROTECTION

Farmers in raven territory should learn to consider the bird a problem variable in importance and to be dealt with as circumstances warrant. Much can be done to protect certain crops by altering farm practices. The loss of chicken and turkey eggs can largely be eliminated by providing suitable enclosed nesting facilities. Small melon, peanut, and corn patches can be planted close to the farmyard, if soil conditions permit, a practice that will more than pay for itself if raven pressure is severe. Often melons can be protected by being sprinkled with lime or having their tops whitewashed or by being covered with sacks when about full grown.

When it does become necessary to adopt some means of protecting crops from raven attack, the urgency of the need and the permanency of the relief desired should dictate the method. If protection must be immediate, the most satisfactory plan is to use frightening devices, which often will prove sufficient when the raven pressure is for only a short period or when natural foods are abundant and control methods impracticable. If more lasting relief is desired, a control program aimed to reduce numbers is required, but this is usually slow in affording relief.

FRIGHTENING DEVICES

The shotgun is without question the best single device for frightening ravens from crops. During the molting season in August and September the birds are particularly shy and consequently easily frightened. It is not necessary to kill the birds; the noise is the chief deterring factor. Shooting with guns as a means of control or of significantly reducing the number of birds, particularly at the roosts, is likely to prove both uncertain and expensive, however.

Carbide exploders (automatic flashguns), so far as is known, have never been tried with ravens. Their use at commercial melon or peanut patches may be worth while, but the regularity and harmlessness of the explosions would soon be detected by the birds.

The traditional scarecrow may give protection for a few days; but unless backed up by some actual destruction, its usefulness is likely to be of short duration. Indeed it must be remembered that most frightening devices are of only temporary value and that it is up to the farmer to outwit the raven.

Numerous other crop-protection practices have been employed by farmers with varied success. In small fields the best results have been produced by stretching wires or strings around and over the fields. This method is usually improved by attaching to the wires or strings bright bits of paper and rags or shining cans, bottles, or mirrors. One farmer reported the successful use of a few posts 10 feet high, each with a 6-foot cross arm at the top from which clear, narrow-necked bottles were suspended. The glistening of the glass and the whistling of the wind over the bottle tops were believed to be the frightening features.

CONTROL MEASURES

When frightening devices fail or when the ravens become so abundant that their numbers must be reduced, there are several control measures that may be used. Those advocated are discussed below.

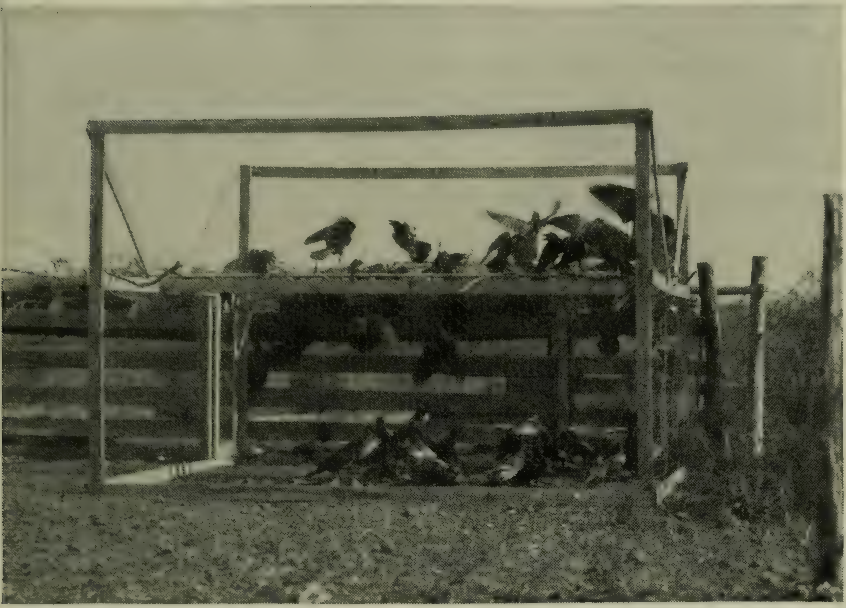

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FIGURE 12.—One night's catch of white-necked ravens (151 in all) in a cage trap.

Intensive and widespread control campaigns cannot be recommended; not only are they unnecessary, but they may reduce the beneficial activities of the birds in sections where they are needed. In practicing control it is well to remember that cruelty is not necessary and adds nothing to the effectiveness of the method.

TRAPPING

Trapping, supplemented under some conditions by patrol with the shotgun, can be recommended as a safe and satisfactory method of control that if properly practiced will provide all the repression necessary. It is most effective during the colder months, after the crops have been harvested and when food is scarce.

LIVE TRAPPING

The most selective and safest means of reducing the numbers of white-necked ravens is by catching them alive in large cage traps[5] of the type known as the Australian crow trap that have demonstrated their efficiency on various occasions (fig. 12). One trap that was operated for 12 days in November caught 512 white-necked ravens; and 4 traps, used at one place from September 1934 until the following spring, caught 10,000. Success depends largely on the proper placement of the traps and on keeping them freshly baited, as well as on removing excess birds at regular intervals.

The birds caught should be killed quickly and humanely and the bodies taken some distance from the trap so as not to act as a deterrent, and the trap and surrounding area should be kept free of feathers and other litter. When the trap is not in use, all bait should be removed and the door tied open, so that any entering birds may escape and not be held to die of starvation.

STEEL TRAPS

Steel traps with heavily padded jaws, set on posts where the ravens reguarly perch or placed near carcasses, may be used to catch a few birds and thus have a deterrent effect on others. If the traps are put on posts, the attached chain should be long enough to reach the ground. Such traps should be visited several times daily.

DESTROYING NESTS, EGGS, AND YOUNG

Destroying the nests, eggs, and young of ravens is an effective control procedure that may be employed by stockmen in extensive pastures where the birds are nesting. Inasmuch as the destruction of nests and eggs early in the season may affect only a small proportion of the raven population, it is desirable to wait until most of the nests contain young birds. Consequently June and July are the months best suited for the work. This method can be made very selective by employing operators who will refrain from destroying the nests of beneficial hawks, owls, and smaller birds.

POISONING

Investigations have shown that where control of white-necked ravens is necessary it can be practiced most effectively and humanely by the use of the cage trap. However, to satisfy the many inquiries made about poison a few remarks regarding its use will not be amiss. Poison as an instrument in bird control should be considered only for species that are seriously destructive and then only as a last resort when all other means have failed.

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[5] For details of construction and operation, see Aldous, Shaler Eugene: A cage trap useful in the control of white-necked ravens. U. S. Bur. Biol. Survey Wildlife Res. and Mgt. Leaflet BS–27, rev., 4 pp., illus. 1938. [Processed.] Free on request from the Fish and Wildlife Service, Washington, D. C.

Poisons that can be used for raven control are not selective in their action, and because of the raven's habit of moving from place to place it is difficult to place the poisons in the field so that ravens only will get them. Extreme care, therefore, must be exercised in their distribution lest desirable species meet the fate intended for the undesirable or lest various legally protected birds be killed and penalties incurred.

Thus, although trained operators have obtained satisfying results with poison in experimental bird control, because of the hazard to beneficial forms of wildlife and domestic stock, as well as to inexperienced operators themselves, its use against ravens cannot be recommended for the general public and poison formulas have purposely been omitted from this report. Should it ever become necessary to resort to the use of poison in raven control, it is imperative that the poison be distributed only under the direct supervision of trained personnel.

EXPLOSIVES

Dynamite has been successfully employed in Oklahoma and a few other States in bombing crow roosts and probably could be used with equal efficacy in roosts of white-necked ravens. Roosts that harbor ravens exclusively, though, are most commonly found in mesquite groves, and the effectiveness of bombs under such conditions has yet to be demonstrated. For this reason and because bombing is a hazardous process that should be carried out only by experienced operators, the details of procedure are not included in this report.

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UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

PREPARATION AND KEEPING QUALITY OF LIGHTLY SMOKED MACKEREL

RESEARCH REPORT 6

UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary
FISH AND WILDLIFE SERVICE
Ira N. Gabrielson, Director

Research Report 6

PREPARATION AND KEEPING QUALITY OF LIGHTLY SMOKED MACKEREL

BY

MAURICE E. STANSBY and FRANCIS P. GRIFFITHS

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ABSTRACT

SINCE at present only heavily smoked mackerel is available, the market for which is limited because of its undesirable flavor, lightly smoked mackerel similar to finnan haddie or kippered salmon should prove much more popular. Such a lightly smoked product has been prepared experimentally. It has a mild smoke flavor, which blends with but does not overshadow the natural mackerel flavor. It is very perishable, but the time during which this product can be kept in good condition can be greatly extended by freezing and holding in cold storage. Brining before smoking and freezing, using moistureproof paper wrappers, and storing at a low temperature retard development of rancidity and permit storage up to 6 months.

PREPARATION AND KEEPING QUALITY OF LIGHTLY SMOKED MACKEREL

By MAURICE E. STANSBY, *Technologist*, and FRANCIS P. GRIFFITHS, formerly *Bacteriologist, Division of Fishery Industries, Fish and Wildlife Service*

CONTENTS

	Page		Page
Introduction	1	Changes during preparation	4
Preparation	2	Keeping quality	5
Brining	2	Cold storage of frozen smoked product	6
Drying	2	Factors influencing rancidity	6
Smoking	3	Conclusions	10
Sampling procedure	4	Literature cited	10

INTRODUCTION

Fish are smoked for two reasons: to preserve them and to develop a distinctive flavor. In the early days, before modern refrigeration and canning methods were developed, salting, drying, smoking, and natural cold were the only means by which fish could be kept for any extended period. Since in smoking fish, preservation was the primary consideration, less attention was paid to developing a desirable flavor, and this tended to produce a heavily smoked product. Such heavily smoked fish were probably not considered delicacies, although a taste was eventually developed for them.

Today, most consumers do not care for a heavily smoked product, and as better methods of preservation are now available, a market for smoked fish must be developed through appealing to taste. There is a widespread demand for lightly smoked foods, as indicated by the popularity of bacon and ham. These products are no longer smoked as a means of preserving the meat but rather because of a considerable demand for them on account of their pleasing taste. The meat is smoked lightly so that the smoke flavor blends with rather than obscures the original flavor of the meat.

With the introduction of modern refrigerating methods such lightly smoked fish products as kippered salmon and finnan haddie have become popular and have a fairly widespread distribution, especially near centers of production. Finnan haddie is made from fresh fish and is retailed immediately, it being nearly as perishable as the fresh product. Kippered salmon is likewise highly perishable. The salmon, caught only in limited seasons, are usually frozen and held in cold storage until needed, when they are withdrawn, smoked, and then eaten at once. Unfortunately, no similar product has been developed from mackerel, and since there is often a surplus of these fish, a study of the production and storage of lightly smoked mackerel was undertaken.

PREPARATION

Seven lots of about 15 mackerel each and totaling about 150 pounds were smoked. The fish were fairly uniform in size and weighed about 1½ pounds each. All were taken in purse seines during July and August, when mackerel contain 12 to 20 percent or more of oil, and were landed 12 to 36 hours after being caught. The largest surplus of mackerel is likely to accumulate during this period, and the prices will consequently be low. The fewer fish caught in either the spring or the fall, although more desirable for smoking because the lower oil content makes them less susceptible to rancidity, are likely to be too expensive for smoking owing to the seasonal demand for fresh fish.

These samples of fish were dressed in two ways. In most cases the heads were removed, the fish split down the backbone, and the viscera removed. In a few instances the fish were filleted. The loss due to the dressing operation was about 40 percent in the first precedure and about 60 percent when fillets were cut. In commercial practice some variation from these values may be expected because dressing losses are dependent on a number of factors, including the size and fatness of the fish, and the degree of skill of the person doing the dressing.

BRINING

The dressed fish were placed in tubs of water for half an hour to remove coagulated blood, which otherwise would leave unsightly blemishes in the final product. They were then brined for 15 minutes in a 10-percent (38.5° salometer) salt solution, used in the proportion of 2 pounds of brine to 1 pound of dressed fish.

Griffiths and Lemon (1934)[1] recommended a 10-percent salt solution and a 30-minute brining period for the preparation of finnan haddie from haddock. Mackerel, however, are smaller fish of more delicate texture, and a shorter brining period proved more satisfactory. Also, it was found desirable to keep the salt concentration at the minimum, because salt accelerates the development of rancidity in fatty fish.

DRYING

In most instances the brine was drained off and the fish were hung overnight in the smokehouse in a current of air created by means of a blower. This treatment produced a glossy surface, or pellicle, which took an even smoke and made a desirable uniform-appearing product.

When the smoking process is to be completed in one day, forced drying may be used. In one experiment, the smokehouse was heated to 100° F., and a current of air drawn through the house by means of a blower. Drying was completed in about 4 hours, and the finished product resembled in all respects that obtained by drying overnight.

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[1] Publications referred to parenthetically by date are listed in Literature Cited, p. 10.

SMOKING

The experimental smokehouse described by Lemon (1932), in which temperature, humidity, and smoke density could be controlled, was used in the investigation. The fish were smoked at a temperature of 100° F. and at as low a relative humidity as possible. Air-dried oak sawdust was used to produce a smoke of moderate density. The low humidity did not cause excessive drying as would be the case with some species of fish, because the initial moisture content of the mackerel, a fat fish, was relatively low, and the water present was not readily driven off.

Fish cold-smoked 1½ hours had a very mild smoke flavor; those cold-smoked 3 to 4 hours had a mild smoke flavor; and those cold-smoked 8 hours had a moderate smoke flavor. One lot was cold-smoked 3½ hours at 100° F. and then an additional hour at 200° F. This yielded a hot-smoked product dark in color and having a strong smoky taste more nearly like that of smoked mackerel procurable in the market. The results of these fish-smoking experiments are shown in table 1.

TABLE 1.—*Results of smoking mackerel for various periods*

Product	Smoking period	Appearance	Smoke flavor
Very light-smoked	Cold-smoked 1½ hours at 100° F	Light brown	Very mild.
Light-smoked	Cold-smoked 3½ hours at 100° F	Medium brown	Mild.
Medium-smoked	Cold-smoked 8 hours at 100° F	Dark brown	Moderate.
Hot-smoked	Cold-smoked 3½ hours at 100° F., then 1 hour at 200° F.	Dark brown to black; tarry.	Strong.

The product obtained by cold-smoking 3 to 4 hours was judged to be the best and was quite different from the smoked mackerel ordinarily offered for sale. The short smoking period imparted a mild smoke taste to the flesh, yet the natural mackerel flavor was not overshadowed by that of the wood smoke, as is often the case with the more heavily smoked product. All who tasted these fish, many of whom did not care for the usual heavily smoked mackerel, declared that they were excellent in quality and had a delicate and pleasing flavor.

Fish smoked 8 hours also had a satisfactory flavor, which was preferred by a few. The wood smoke taste was more pronounced and was intermediate between that of the fish smoked 3 to 4 hours and that of regular commercial smoked mackerel.

SAMPLING PROCEDURE

There is considerable variation, particularly in the oil and water contents, of individual mackerel in the same lot. This complicates a study of the changes occurring during the preparation and storage of smoked mackerel, inasmuch as the difference that may exist initially between the individual fish may be greater than that caused by the method of preparation or by storage conditions. Hence the difference in flavor of two samples of mackerel, one of high and the other of low oil content, may be so great as to prevent an accurate appraisal of the difference caused by a light and a medium smoking process. In order to eliminate so far as possible such sources of error, all comparative analyses and tests were made on different parts of the same fish. Mackerel were cut into pieces, which were then subjected to different smoking processes and held for subsequent analyses, or the pieces smoked by one particular method were stored in various ways to test keeping quality or rancidity development.

CHANGES DURING PREPARATION

The fish samples were analyzed to determine changes in moisture content due to brining, drying, and smoking. The hot-smoked fish lost the most moisture, and the very lightly smoked ones the least. The brining process produced little change in the moisture content, and the drying operation caused a loss in weight of only about 6 percent. Table 2 shows the percentage of loss in weight of the fish at the different stages of the smoking process. In the last column is given the estimated yield from 100 pounds of dressed fresh fish smoked by various methods.

Bacterial counts were made after each step of the process, using the method described by Griffiths and Stansby (1934). Brining and drying showed no consistent effect on the bacteria. Cold-smoking substantially reduced the bacterial count, but the product was still far from sterile, with counts of 36,000 to 260,000. The hot smoke, however, almost completely sterilized the product.

TABLE 2.—*Loss in weight of fish at different stages of the smoking process, and the estimated yield from 100 pounds of dressed fresh fish smoked by various methods*

Smoking process	Loss in weight at each stage			Estimated yield from 100 pounds
	Sample 1	Sample 2	Average	
	Percent	*Percent*	*Percent*	*Pounds*
Brining	[1] 0.4	0.3	[1] 0.1	100.1
Drying	5.8	6.4	6.1	94.0
Very light-smoking	1.2	[1] 1.8	[1] .3	94.3
Light-smoking	17.0	16.0	16.5	78.5
Medium-smoking	20.2	20.0	20.1	75.1
Hot-smoking	27.7	27.5	27.6	68.1

[1] Increase in weight.

Tests were also made to determine the increase or decrease in the peroxide number and the free fatty-acid content of the oil in smoked mackerel by the method described by Stansby (1935). No change in peroxide number was noted during the smoking process, the value remaining zero throughout, and no rancidity could be detected by tasting the final smoked product. The free fatty-acid values were probably meaningless as such, since they included not only acid from the oil of the fish but also acetic and other acids absorbed by the fish from the wood smoke. The acidity increased proportionately with the duration of the smoking process, a maximum value of 0.035 percent calculated as acetic acid in the flesh being attained after 8 hours of smoking.

KEEPING QUALITY

Tests to determine the keeping quality of mackerel cold-smoked for 3½ hours were conducted by storing samples in an incubator at 37° C. (99° F.), in a room at 25° C. (77° F.), and in an ice chest at 9° C. (48° F.). Unsmoked control fillets were stored under similar conditions. At the end of 2 days the smoked samples stored at 37° C. were in good condition, whereas the unsmoked controls were very stale. When stored at 25° C., the smoked fish kept in good marketable condition for 3 days, but the unsmoked for only 1 day; and when stored at 9° C., the smoked product was only slightly rancid at the end of 5 days, while the unsmoked fillets were slightly stale in 3 days. Table 3 shows the keeping quality of cold-smoked and unsmoked mackerel.

TABLE 3.—*Keeping quality of mackerel cold-smoked 3½ hours compared with that of unsmoked mackerel*

Storage period in days	Condition of fish stored at various temperatures					
	37° C. (99° F.)		25° C. (77° F.)		9° C. (48° F.)	
	Smoked	Unsmoked	Smoked	Unsmoked	Smoked	Unsmoked
2	Good	Very stale	Excellent	Stale	Excellent	Good.
3	Very stale	Putrid	Good	Very stale	Good	Slightly stale.
4	Putrid	do	Stale	Putrid	Slightly rancid	Rancid.
5	do	do	Very stale	do	do	Stale; rancid.
9	do	do	Putrid	do	Stale; rancid	Putrid.

Light and medium cold-smoked mackerel and the hot-smoked product were stored for 8 days at 25° C. After this period the light-smoked fish were putrid and rancid, the medium-smoked fish were stale and rancid, but the hot-smoked fish were still satisfactory though slightly rancid. Both of the cold-smoked fish samples had bacterial counts of 100,000,000 per gram of flesh while the hot-smoked sample showed a count of 500,000 mold organisms. These experiments demonstrate that cold-smoked mackerel are practically as perishable as fresh untreated fish. The better keeping quality of the hot-smoked mackerel can be attributed to greater reduction in moisture content and bacterial count during the smoking operation.

COLD STORAGE OF FROZEN SMOKED PRODUCT

Since lightly smoked mackerel is so perishable a product, experiments were undertaken to determine the feasibility of freezing and cold storage. Smoked split mackerel were cut into two pieces without removing the bone, and the pieces were wrapped in moistureproof paper and frozen by placing them in a mechanical refrigerator at 0° F. After freezing, some were placed in commercial cold-storage rooms and the rest were left in the mechanical refrigerator. At intervals pieces were withdrawn and thawed, the appearance was noted, and the fish were cooked and tasted by a number of persons. Bacterial counts were made before and after freezing the fish and after they had been kept in storage for suitable intervals.

Freezing, as would be expected, caused a substantial reduction in the bacterial count, for example, from 29,000 to 4,500; from 100,000 to 4,000; and from 15,000 to 8,000; but none of the pieces was sterile. Counts were almost invariably reduced to less than 10,000 per gram of flesh. Upon subsequent storage at 0° F., the bacterial count slowly diminished irregularly, until after 6 months of storage values were from 1,000 to 100 per gram.

The thawed product in appearance resembled the unfrozen pieces in all respects except that the gloss was less pronounced. No appreciable amount of drip formed, nor did the thawed pieces have the coarse, porous look sometimes observed in frozen fish.

Upon prolonged storage of the frozen smoked mackerel, the most important change noted was a fairly rapid development of rancidity, and this was the determining factor in limiting the period of storage. Accordingly, several series of smoked mackerel were frozen and stored under different conditions to determine the best methods of minimizing rancidity.

FACTORS INFLUENCING RANCIDITY

Freshly smoked mackerel fillets of the various series were wrapped in moistureproof paper, frozen in air at 0° F., and then stored at that temperature. After 3 months of storage, the lightest smoked fillets were already rancid, but the others showed only a slight degree of rancidity. (Table 4.) After 6 months of storage all fillets exhibited definite rancidity, although this was somewhat masked by the woodsmoke flavor. The degree of rancidity in such cases was revealed through the prolonged aftertaste.

Mackerel fillets cold-smoked 3½ hours were wrapped in moistureproof papers, frozen in air at 0° F., and then stored at 26°, 15°, and

−5° F. After 6, 15, and 28 weeks in cold storage, some of the pieces were withdrawn, thawed, cooked, and tasted. Table 5 shows the results of these tests.

TABLE 4.—*Keeping quality of frozen smoked mackerel stored at 0° F. for 3 and 6 months*

Smoking treatment	Condition of fish after—	
	3 months	6 months
Very light cold-smoked	Rancid	Very rancid.
Light cold-smoked	Good; definite aftertaste	Rancid.
Medium cold-smoked	do	(1).
Hot-smoked	do	(1).

[1] These fish had such a strong smoke flavor as to render rancidity tests unreliable. The strong aftertaste indicated that they were at least somewhat rancid.

The samples stored at 26° F. were rancid within 6 weeks, and upon further storage the bacterial count rose and putrefaction set in. This temperature is altogether too high for successful preservation of smoked mackerel. Pieces stored at 15° F. evidenced no putrefaction even after more than 6 months of storage, but rancidity developed slowly, the fish being definitely rancid, though not inedible, after 15 weeks. The fish stored at −5° F. were still in good condition, showing no signs of rancidity, at the end of 6 weeks of storage, and even after 6 months were only slightly rancid.

TABLE 5.—*Effect of storage at 26°, 15°, and −5° F. on the keeping quality and peroxide number of frozen mackerel that had been cold-smoked 3½ hours*

Storage time in weeks	Condition of fish stored at—					
	26° F.		15° F.		−5° F.	
	Peroxide number	Condition	Peroxide number	Condition	Peroxide number	Condition
6	20	Rancid	12	Slightly rancid	0	Fresh.
15	22	do	22	Rancid	10	Slightly rancid.
28	26	Stale; rancid	24	do	11	Do.

It is evident that frozen smoked mackerel must be stored at a low temperature, preferably at 0° F. or less if rancidity is to be minimized, and even at that low temperature rancidity slowly develops.

Frozen fish stored other than in the round are usually wrapped in some kind of moistureproof wrapping material. This serves to prevent the evaporation of moisture and the consequent drying of the product, which results in loss in weight and detracts from the value by altering texture and appearance. In storing such oily fish as mackerel the wrapper also minimizes rancidity by decreasing exposure to air.

Series of samples of smoked mackerel were wrapped or covered in various ways, weighed, and frozen. After 2 months of storage at

0° F., the loss in weight and the degree of rancidity were noted. The data in table 6 indicate that the protective materials can conveniently be separated into three groups according to their efficiency.

The first and most efficient group of protective materials included transparent moistureproof paper wrappers used either alone or in combination with a waxed cardboard carton or a wooden box, and a waxed carton only. The fish in this lot after 2 months of storage showed a loss in weight of less than 1 percent and were imperceptibly or only very slightly rancid. The materials in the second group were an unwaxed carton, waxed paper wrappers and wooden box, and mineral oil glazes. These samples lost between 1 and 2 percent of their original weight in 2 months and were very slightly to definitely rancid. In the third lot either no protective device was used or a heavy mineral oil was applied, which proved only slightly better than no treatment at all. The mackerel in this group lost between 2 and 4 percent of their original weight in 2 months and were then definitely rancid.

These results indicate that desiccation is not a serious problem with frozen smoked mackerel except when the fish are stored for a long period. It is recommended, however, that a good wrapping material be used in order to decrease losses through rancidity. For this purpose a good grade of moistureproof paper is probably the best. If such a paper is used, care must be taken that the fish are carefully wrapped and sealed. Waxed cardboard cartons prove very satisfactory for packing the mackerel.

TABLE 6.—*Effectiveness of various protective materials in retarding rancidity and desiccation in frozen smoked mackerel stored at 0° F. for 2 months*

Protective material	Rancidity	Desiccation	Loss in weight
		Percent	*Percent*
Transparent moistureproof paper wrappers and waxed carton.	None to very slight	0 to 1	0
Transparent moistureproof paper wrappers and unwaxed carton.			0
Waxed carton			0.3
Transparent moistureproof paper wrappers and wooden box.			.5
Do			.6
Unwaxed carton	Very slight to definite	1 to 2	1.2
Waxed paper wrappers and wooden box			1.5
Light mineral oil glaze			1.1
Medium mineral oil glaze			2.0
Heavy mineral oil glaze	Definite	2 to 4	2.6
No treatment			3.5

The degree of rancidity noted in the smoked product was greater than that which ordinarily develops in frozen mackerel, since these fish frozen in the round and kept well glazed are only slightly rancid after 3 to 6 months of storage. This increase is surprising because smoke is considered an antioxidant capable of retarding rancidity in most products. A preliminary experiment was conducted to determine the antioxidant effect of wood smoke on mackerel oil. The oil was prepared by stirring ground mackerel flesh with ether and anhydrous sodium sulfate, filtering the ether solution through cotton, and carefully evaporating the ether. The oil so obtained was divided into two parts, and one part was treated by bubbling through it wood smoke made from oak sawdust. Both the treated and the untreated oil were then stored at −25° C., 10° C., and 35° C. The results, as shown in table 7, indicate that wood smoke does possess antioxidant properties, as in each case the treated oil, after 43 weeks of storage, showed lower peroxide numbers and had less rancid flavor than the untreated oil. Takahashi and Mosuda (1938) reported similar results for herring oil.

TABLE 7.—*The antioxidant effect of wood smoke on mackerel oil*

Storage period	Peroxide values at different storage temperatures					
	−25° C. (−13° F.)		10° C. (50° F.)		35° C. (99° F.)	
	Smoked	Unsmoked	Smoked	Unsmoked	Smoked	Unsmoked
Before storing	1.0	1.2	1.0	1.2	1.0	1.2
43 weeks	1.3	9.9	5.4	45.6	24.9	34.0

Salt is known to have an accelerating influence on rancidity. Recently Banks (1938) showed that salt hastens the development of rancidity in frozen herring. A few experiments were conducted to determine whether the preliminary brining before smoking could be responsible for the increased rate of rancidity development in smoked mackerel. Pairs of mackerel fillets, in which one of each pair received no treatment and the other was dipped in a 10-percent salt solution exactly as were the smoked mackerel, were wrapped in moistureproof paper and stored at 0° F. The salted fillets became rancid within 2 months, while the untreated ones were only slightly rancid after 6 months.

These results indicate that the preliminary brining treatment should be as short as possible in order that the development of rancidity in the smoked product kept in storage may be retarded. If the mackerel are to be stored for more than 6 months, it may be necessary to omit the brining process, although this will alter the flavor and the fillets will not have the normal glossy surface.

The more rapid development of rancidity in frozen smoked mackerel than in frozen mackerel suggests the possible advantage of holding surplus mackerel frozen and preparing the smoked product from the frozen fish. In preliminary tests, however, frozen mackerel failed to develop the smooth, glossy surface considered desirable in smoked fish. Unfortunately, it became necessary at that time to discontinue further studies on smoked mackerel because the laboratory was moved from Gloucester, Mass., to College Park, Md.

CONCLUSIONS

The present market for smoked mackerel is limited as only a heavily smoked product is available, which is not popular with most consumers because of undesirable flavor. A lightly smoked product similar to finnan haddie or kippered salmon should find a much wider market.

A satisfactory lightly smoked mackerel has been prepared experimentally. It has a mild smoke flavor, which blends with but does not overshadow the delicate, normal mackerel flavor.

Lightly smoked mackerel is nearly as perishable as the fresh, unsmoked fish and must be handled accordingly.

The period during which smoked mackerel may be kept in good condition can be greatly increased by freezing the product and holding it in cold storage.

The storage time of frozen smoked mackerel can be increased by shortening the preliminary brining period before smoking, by using a moistureproof wrapper after smoking, and by storing at as low a temperature as possible, preferably below 0° F. These precautions retard the development of rancidity and permit storage for periods up to 6 months.

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PRINCIPLES AND METHODS IN THE CANNING OF FISHERY PRODUCTS

RESEARCH REPORT No. 7

UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary
FISH AND WILDLIFE SERVICE
Ira N. Gabrielson, Director

RESEARCH REPORT No. 7

PRINCIPLES AND METHODS IN THE CANNING OF FISHERY PRODUCTS

By
NORMAN D. JARVIS

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ABSTRACT

CANNING is the most important factor in the fishery industry today, but information concerning the principles of canning fishery products has not been assembled, nor has a description of modern canning methods been previously available. This report is a reference handbook on problems in the commercial canning of fishery products. In addition to discussing the scientific principles on which canning is based, it outlines the various engineering problems faced by the canner, and gives a detailed description of the methods used today in the commercial canning of 58 varieties of fish and shellfish packed commercially in hermetically sealed containers. Information on spoilage and methods used in the examination of fishery products is of use to the laboratory worker. The discussion on fishery products as food is of benefit to producers, brokers, dealers, food technologists, home economists, consumers, and all others interested in foods and their use.

PRINCIPLES AND METHODS IN THE CANNING OF FISHERY PRODUCTS

By **NORMAN D. JARVIS**, ***Technologist, Division of Fishery Industries, Fish and Wildlife Service***

CONTENTS

Page

- Introduction vii
  - Historical outline of the canning of fishery products 1
  - Statistics on production of canned fishery products 7
    - Number of plants and distribution according to products 7
    - Geographical distribution of industry 8
- Principles involved in canning seafoods 15
  - Relation of micro-organisms to canning 15
  - Sterilization 17
    - Condition of raw material 18
      - Freshness 18
      - Maturity 19
    - Fill of container 19
      - Heat penetration 19
      - Vacuum 20
      - "Cut-out" weight 20
      - Corrosion 20
      - Strain on containers 21
    - Consistency of product 21
      - Starch content 21
      - Size of particles 21
    - Composition of container 21
      - Conduction 22
      - Thickness of container walls 22
    - Size of Container 22
    - Initial temperature 23
    - "Coming-up" time 23
    - Retort temperature 23
    - Mode of heat transfer 24
      - Conduction 24
      - Convection 24
    - Time and temperature relationships 25
    - Water in the retort 25
    - Air in the retort 26
      - Dalton's law 26
      - Removal of steam by condensation 26
      - Temperature–pressure relationship 27
    - Thermal death time 27
    - Vacuum 28
    - Cooling 29
    - Added acids 29
    - Altitude 30
    - Oil content 30
    - Stratification 30
  - Vacuum in canned fishery products 31
    - Collapsed ends 31
    - Can strains 31
    - Reduction of chemical activity 31
    - Factors influencing vacuum 32
      - Temperature and altitude 32
      - Method of exhaust 33
        - Heat exhaust 33
        - Mechanical exhaust 34
      - Headspace or fill of can 34
        - Expansion of contents 34
        - Vapor pressure 34
        - Expansion of gases 35
      - Delay between exhausting and seaming 36
      - Loose seams 36
      - Freshness of product 36
      - Expansion rings and weight of tin plate 37
      - Solubility of headspace gases and absorption of oxygen 37
      - Temperature at which vacuum is taken 38
- Factors to be considered in establishing a cannery 39
  - Supply of raw material 39
  - Suitable cannery site 39
  - Length of canning season 40
  - Transportation 40
  - Labor supply 41
  - Water supply 42
  - Management 42
  - Marketing and sales 43
  - Capital 44
- Factors in cannery construction 44
  - Space needed 44
  - Division of space 45
  - Location of cannery buildings 46
  - Storage bins 46
  - Cleaning 47
  - Type of construction 47
  - Ceilings and ventilation 48
  - Floors 48
  - Docks 48
  - Lighting 49
  - Conveyors 49
  - Steam supply 49
  - Refrigeration 50
  - Cost of construction 50
- Containers and packages 51
  - Introduction 51
  - Glass containers 52
    - Manufacture of glass and glass containers 52
  - Tin cans 53
    - Composition of tin plate 54
    - Can manufacture 54
      - Cutting body blanks 54
      - Body making 55
      - Flanging 57
      - Double seaming 57
      - Can testing 57
      - Manufacture of can ends 58
      - Stamped or pressed containers 59
    - Shipping containers 59
      - Wooden boxes 59
      - Fiberboard boxes 64
- Important factors in the operation of canning machinery 67
  - Butchering or cleaning machines 67
  - Precooking or preparation machines 68
  - Can closing machines or double seamers 69
    - Machine parts in the closing machine 69
    - Forming the double seam 70
    - Adjustment of seaming heads 74
    - Visual inspection of can seams 76
    - Seam gauges 77
    - Lubrication 78
    - Conclusion 78
  - Can washers 79
  - Retorts or cookers 80
    - Vertical retorts 80
    - Horizontal retorts 81
    - Agitating cookers 81
    - Retort or cooker requirements 81

Page

- Cooling and cleaning the processed can 82
- Sanitation in canning 89
  - Why sanitation is needed 89
  - Public health regulations and sanitary codes 89
  - Refrigeration 90
  - Raw material handling 90
  - Use of wooden equipment 91
  - Personal hygiene 91
  - Cans 92
  - Cleaning equipment 92
  - Handling waste 92
- Operations involved in canning 93
  - Securing the raw material 93
  - Transporting and receiving 95
  - Grading 97
  - Dressing and washing 97
  - Preparation for the can 98
  - Filling 98
  - Exhaust or vacuum and sealing 99
  - "Processing," "cooking" or "sterilizing" 100
  - Cooling and washing 101
  - Coding 101
  - Lacquering 102
  - Warehousing 102
  - Labeling 103
- Brines and other added ingredients 112
  - Brines 112
  - Oils 113
  - Vinegar and spices 114
  - Mustard sauce 115
  - Tomato sauce 116
- Pacific salmon 117
  - Species of Pacific salmon 117
    - Chinook 118
    - Red 118
    - Medium red 120
    - Pink 120
    - Chum 120
    - Steelhead trout 120
  - Fishing seasons 121
  - Fishing gear and methods 122
    - Gill-net fishing 122
    - Haul-seine or beach-seine fishing 124
    - Purse-seine fishing 124
    - Pound nets or traps 126
    - Trolling 130
    - Reef-net fishing 130
  - Transporting and receiving 132
  - Grading 133
  - Dressing and washing 133
  - Preparation for the can 134
  - Filling 135
    - The collapsed can 136
  - Inspection and weighing 137
  - Exhausting and sealing 137
  - Processing, cooking, or "sterilizing" 138
  - Washing the cans 140
  - Lacquering 141
  - Labeling 141
  - Boxing or casing 142
  - Floating canneries 142
  - Canned salmon inspection 143
- Sardines 147
  - Maine sardines 147
    - Fishing area and season 147
    - Securing raw material 147
      - Weirs 148
      - Seines 148
    - Transporting and receiving 149
    - Grading the raw herring 150
    - Dressing or cleaning 151
    - Preparing for the can 152
      - Brining 152
      - Flaking 153
      - Precooking 153
        - Steaming 153
        - Frying 154
    - Filling 155
    - Exhausting and sealing 157
    - Processing 157
    - Cooling and washing 158
    - Labeling and storage 158
    - Inspection 159
  - Pacific coast sardines 160
    - Fishing area and season 160
    - Fishing gear and methods 161
    - Transporting and unloading 162
    - Dressing and washing 164
    - Preparing for the can 165
      - Brining 165
      - Drying 165
      - Oil fry 166
      - Raw vacuum pack 167
      - Broiled pack 167
      - Precook packs 167
    - Draining 168
    - Filling with sauce 169
    - Specialty packs 169
      - Sardines in brine 169
      - Sardines in oil 170
      - Sardine fillets 170
      - Smoked fillets 171
      - Smoked sardines in tomato sauce 171
    - Sealing 171
    - Washing 172
    - Processing 172
    - Inspection and examination 173
- Tuna 175
  - Species canned 175
    - Yellowfin tuna 175
    - Bluefin tuna 175
    - Skipjack 176
    - Albacore 176
    - Bonito 176
    - Yellowtail 177
    - Miscellaneous 177
  - Fishing areas 177
  - Fishing craft 178
  - Fishing methods 179
  - Transporting and unloading 181
  - Thawing 183
  - Dressing or butchering 186
  - Precooking 187
  - Cleaning 188
  - Packing 190
    - Cutting 190
    - Grading 191
    - Filling 191
  - Exhaust or vacuum and sealing 193
  - Washing 194
  - Processing 194
  - Cooling 195
  - Storage and labeling 196
  - Specialty packs 196
    - Tonno 196
    - Tuna in glass 196
    - Tuna in aluminum cans 196
    - Creamed tuna 197
    - Garlic flavored tuna 197
    - Ventresca 197
  - Inspection and examination 198
- Mackerel 199
  - Eastern or "Boston" mackerel 199
  - Pacific mackerel 200
    - Fishing area and methods 200
    - Transporting and unloading 202
    - Cleaning or butchering 203
    - Brining 204
    - Filling 204
    - Precooking or exhausting and sealing 205
    - Processing and cooling 206
  - Mackerel, tuna style 206
  - Mackerel fillets 206
- Miscellaneous fish 209
  - Alewives 209
  - Eels 210
    - Smoked eels 212
    - Pickled eels 213
  - Finnan haddie 213
  - Fish flakes 214
  - Herring 217
    - Kippered herring 217
    - Herring in tomato sauce 218
  - Animal food 218
    - Atlantic Coast method 218
    - Pacific Coast method 219
  - Shad 221
    - Kippered shad 222
  - Sturgeon 223
    - Plain or in tomato sauce 223
    - Kippered or smoked sturgeon 223
- Shellfish 225
  - Clams 225
    - Butter clams and little neck clams 225
    - Hard clams 227
    - Razor clams 229
    - Soft clams 233

Page

  - Clam juice, broth, or nectar 236
- Mussels 236
  - Jellied mussels 238
- Oysters 238
  - Eastern or Gulf oyster industry 238
    - Securing raw material 239
    - Fishing season 240
    - Transporting and receiving 240
    - Steaming 241
    - Shucking 243
    - Washing 243
    - Inspection and grading 244
    - Filling 244
    - Exhaust or vacuum and sealing 245
    - Processing 245
    - Cooling and washing 246
    - Storage, labeling and shipping 246
    - Examination of canned oysters 246
  - Pacific oysters 247
    - Obtaining raw materials 247
    - Transporting and receiving 248
    - Precooking 248
      - Batch process 248
      - Continuous precook 250
    - Washing and grading 251
    - Filling 252
    - Exhausting and sealing 253
    - Processing 254
    - Cooling, washing and storage 254
  - Smoked oysters 254
      - Smoking 255
      - Filling 255
      - Exhausting and closing 255
      - Processing and cooling 256
- Squid 256
  - Raw pack 257
- Crustacea 259
  - Crab 259
    - Dungeness crab 259
    - King crab 263
    - Blue crab 266
  - Lobster 267
  - Shrimp 271
    - Fishing area and extent of industry 271
    - Fishing methods 272
    - Transporting the catch 273
    - Washing and inspection 275
    - Picking 276
    - Preparation for the can 277
      - Washing 277
      - Blanching 277
      - Drying 278
      - Inspection and grading 279
    - Filling 280
    - Exhaust and sealing 280
    - Processing or retorting 282
    - Cooling and washing 282
    - Storage, labeling and shipping 282
    - Shrimp packed in glass 283
- Specialty products 285
  - Clam chowder 285
    - Manhattan style chowder 285
    - New England clam chowder 286
  - Fish chowder 287
  - Fish cakes 290
  - Fish balls (Fiskeboller), Norwegian style 291
  - Turtle and terrapin products 292
    - Green turtle soup 292
    - Snapping turtle soup 293
    - Snapping turtle stew 294
    - Terrapin stew 295
  - Frog legs 296
  - Crawfish bisque 296
- Fish roe and caviar 299
  - Alewife (river herring) roe 299
  - "Deep sea" fish roe 300
  - Shad roe 301
  - Sturgeon caviar 302
  - Whitefish caviar 304
  - Salmon caviar 305
  - Salmon eggs for bait 306
- Canned products hermetically sealed but not processed 309
  - Anchovies 309
    - Spanish or Italian anchovies 309
    - Norwegian or Swedish anchovies 310
  - Codfish 311
  - Smoked herring 312
  - Smoked salmon 312
  - Spiced herring 314
    - Cut spiced herring 315
    - Rollmops 315
    - Bismarck herring 315
  - Oysters 315
  - Crab meat (Pacific coast and Alaska) 318
  - Shrimp meat (Alaska) 319
  - Seafood cocktails 320
    - Cocktail sauces 321
- Spoilage in canned fishery products 323
  - Classification of spoiled cans 323
  - Physical and chemical deterioration 324
    - Discoloration 324
      - Blackening 325
      - Copper sulfide discoloration 325
      - Discoloration caused by processing times and temperatures 326
      - Stack burning 326
    - Perforation and corrosion 326
    - Foreign tastes 327
    - Undesirable textures 327
    - Freezing 328
    - Rusting 328
    - Faulty technique 330
    - Unsuitable products 330
  - Spoilage by micro-organisms 331
    - Gaseous spoilage 331
    - Nongaseous spoilage 332
- Examination of canned fishery products 335
  - Description of lot 335
  - Sampling 336
  - Bacteriological examination 337
    - Preparing the sample 338
    - Taking the sample 338
    - Direct microscopic examination 338
  - Physical and organoleptic examination 339
    - Quality when caught 339
    - Quality when canned 340
      - Odor 340
      - Texture 342
      - Reddening of the flesh 342
      - Honeycombing 342
      - Turbidity of liquid 343
    - Workmanship in packing 343
      - External appearance 343
      - Vacuum 343
      - Headspace 344
      - Amount of liquid 344
      - Fill 344
      - Cleaning 345
      - Color 346
      - Cook 346
      - Seasoning 346
      - Flavor 347
      - Net weight 347
  - Chemical examination 347
  - Records 348
- Cannery inspection 350
  - Types of inspection 350
    - Advantages and disadvantages 352
  - Requirements for a cannery inspector 352
  - Conduct of a cannery inspection 353
- Canned fishery products as food 355
  - Nutritive value 355
    - Determining food value 355
    - Proteins 356
    - Oils and fats 356
    - Mineral elements 358
    - Vitamins 359
  - Appetite appeal 360
  - Amount of waste 360
  - Cost 360
  - Variety of choice 361
  - Ease of purchase 362
  - Ability to purchase in convenient amounts 362
- Literature cited 363

LIST OF ILLUSTRATIONS

Figure		Page
1	Production of canned fishery products 1929–37	9
2	Temperature-altitude relationship in vacuum	33
3	Temperature-vacuum relationship in the canning of salmon	38
4	Old type soldered or hole-in-cap can and modern can	55
5	Diagram illustrating steps in manufacture of cans and can ends	56
6	Can sealer rolls and sketch of can showing different parts	71
7	Correctly and incorrectly formed can seams	73
8	Correctly and incorrectly adjusted can-sealer rolls	75
9	Test wire and waves in cover hook of can lid	76
10	Can seam gauge and micrometer	78
11	Diagram of vertical retort equipped for pressure cooling	85
12	Salmon gill net	123
13	Salmon beach or haul seine and trammel net	125
14	Salmon purse seine	127
15	Salmon trap with driven supporting piles	128
16	Salmon trolling	129
17	General layout of typical salmon cannery	131
18	Salmon canning; unloading and butchering	133
19	Salmon canning line; fish bin, fish cutter and can filler	134
20	Reforming collapsed cans	135
21	Salmon canning; filling and closing cans	137
22	Salmon canning line; clincher, can washer and closing machine	138
23	Salmon canning; washing cans; loading and transferring cans to retort for cooking	139
24	Salmon canning line; closing machine, can washer, retorts	140
25	Salmon canning; removing cans after retorting, washing cans, and transfer to warehouse	141
26	Salmon canning; labeling and casing	141
27	Flow sheet of Maine sardine canning	151
28	Maine sardine canning; packing cans in cases	159
29	Elevator and conveyor at a sardine cannery	162
30	Elevator from unloading pump to automatic scales at a sardine cannery	163
31	Steam exhaust type of precooker	168
32	Floor plan showing equipment layout of a sardine and mackerel cannery	169
33	Battery of can sealing machines in sardine cannery	172
34	Unloading tuna; preparing to swing cart of tuna onto the wharf	183
35	Unloading tuna; unhooking chains before running cart into cannery	184
36	Flume conveyor	185
37	Floor plan of typical California tuna cannery	186
38	Cleaning cooked tuna	189
39	Cutting cooked tuna for the can	190
40	Oil–dispensing apparatus used in tuna canning	193
41	Horizontal retort used in processing tuna	195
42	Elevator and conveyor for unloading mackerel and sardine boats	202
43	Flow sheet for canning alewives or river herring	211
44	Canning fish flakes; removing skin and bones after precooking	215
45	Filling cans with fish flakes	216
46	Canning pet food from fish waste	219
47	Floor plan showing equipment layout of cannery for butter clams	225
48	Details of dressing and cleaning razor clams for canning	231
49	Oyster washer and oyster cars	241
50	Floor plan of typical Gulf oyster cannery	243
51	Loading steaming cars of Pacific oysters from receiving bin	249
52	Steamed Pacific oysters emerging from retort	249
53	Filling cans with Pacific oyster meats	253
54	Floor plan of Pacific oyster cannery	254
55	Flow sheet illustrating procedure in canning Dungeness or Pacific crab	261
56	Dungeness crab and cans of crab meat showing method of filling	263
57	Flow sheet of a typical lobster cannery	269
58	Unloading, washing and inspection of shrimp	274
59	Floor plan of a typical shrimp cannery	277
60	Inspecting the cooked shrimp meats	279
61	Filling the containers with shrimp and checking fill–in weight	281
62	Flow sheet of clam chowder canning	287
63	Flow sheet of fish chowder canning	288
64	Flow sheet for the canning of fish cakes	290
65	Relative protein value of various species of fish and of beef	357
66	Comparison of prices of meat and canned fish	361

INTRODUCTION[1]

Canning is our most important method of food preservation and the only one that has been entirely developed during modern times. Drying and smoking originated in prehistoric ages. Salting and pickling were developed in the early dawn of the historic period. Natural ice has been used for many years for refrigeration. Canned foods were entirely unknown before the Napoleonic era, so that the progress of this industry has been extremely rapid. Seafoods were among the first products canned, and until very recent years our great midwestern regions would have been unacquainted with such appetizing and healthful foods as oysters, shrimp and salmon were it not for canning. Canned foods have been marketable more readily than foods preserved in other ways and their sale has been constantly increasing. Therefore, attention has been devoted largely to developing new canned products and increasing production to meet demand.

The early development of the industry was through empirical means; that is, through trial and error methods, but that stage of development is past. Today, the industry must depend on scientific study of the principles on which preservation by heat in hermetically sealed containers is based, for the maintenance and extension of its wide market and its ability to sell a product of standard and dependable quality. Although there has been great progress in this field in the years following the World War, the information concerning the principles of canning fish and seafoods, together with a description of up to date methods, has not been assembled. Consequently, it is believed that a discussion of the subject will be of general interest.

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HISTORICAL OUTLINE OF THE CANNING OF FISHERY PRODUCTS

A number of individuals contributed to the early development of the canning industry. Although national pride with its consequent tendency to bias often places varying emphasis on the importance of these contributions, it is generally agreed that the original inventor of the art of canning was Nicolas Appert, a Frenchman, and that the basic methods of the industry are the result of his work.

In 1795 the revolutionary French Government was at war on land and sea with most of the other European governments in areas as widely separated as the West and East Indies. Few ports were open to the French, who therefore had to depend largely on dried, smoked and pickled foods brought from France. These products were subject to spoilage and their use resulted in the widespread incidence of deficiency diseases, such as scurvy, which greatly weakened the military forces. The French Government therefore offered a prize of 12,000 francs to anyone who would develop a new method of preserving food so that decomposition would be reduced and more of the original characteristics of fresh food retained.

Nicolas Appert, a confectioner, brewer, distiller and wholesale caterer was interested in this problem. The story of his efforts at a solution is well worth reading (Anonymous, 1924, 1937).

Appert worked until 1804 before he attained his first measure of success and not until 1809 was his method finally developed. He was awarded the prize in that year after a thorough investigation of his method, and as required by the terms of the award his results were published in 1810 (Collins, 1924).

The house of Appert is still in operation under the management of the fourth generation of the family. Appert never became a great commercial success as he was interested in improving his products and processes to the exclusion of almost everything else, and devoted most of his time and money to this end.

Peter Durand, an Englishman, in 1810 obtained a patent on a process for preserving "animal, vegetable and other perishable foods in vessels of glass, pottery, tin or any fit materials." This was the first mention of tin as a container for sterilized foods, although tin containers had been in use before 1800 for packing salt and kippered fish. Durand is said to have obtained his patent through knowledge imparted by a foreigner who is believed to have been Appert. Durand's method came into extensive use only after 1820 when Pierre Antoine Angilbert invented a tin container less subject to leakage, and which could be made more rapidly than formerly.

Canning was first developed on an extensive commercial scale in the United States and most of our pioneer canners were primarily packers of fish and seafoods; packing fruits, vegetables and preserves as secondary or incidental items. Strangely enough, the packing of fishery products presents more difficulties than processing other types of foods.

Canning is said to have been introduced into the United States by Ezra Daggett and Thomas Kensett in 1819 when they packed oysters and other seafoods in New York (Cobb, 1919). William Underwood is credited with establishing a plant in Boston in 1820, packing lobster and fruit in glass. It is understood that these men learned the art in England before emigrating to this country. The Underwood plant was later reorganized into the firm of Wm. Underwood's Sons and is still in existence, the oldest in the United States.

Thomas Kensett was the first to break away from home kitchen methods and deserves credit for the development of the first canned product to receive wide distribution; namely, the oyster. The pioneer development of the industry in the Chesapeake Bay area, the first important canning center, is due to his efforts. Others are said to have engaged in the industry in the Baltimore area before Kensett and as stated above it is believed that oysters were canned as early as 1819. The first systematic effort at the large scale development of a product was made by Kensett in 1844, when he began packing oysters in Baltimore. Collins (1924) reported:

> Oysters and seafood were the first products that became popular. Inland cities could get fresh Baltimore oysters packed in ice through the winter; but folks in smaller places seldom enjoyed such a luxury—the countryman's greatest treat when he went to town was an oyster stew. Baltimore and Boston canned oysters so they would keep for months, and could be bought at any country grocery store by people who had never eaten a fresh oyster.

Increase in production was gradual over a period of about 20 years beginning in 1844. The first big increase in demand came with the Civil War. Preserved foods were needed for feeding the troops, thus enormously increasing the demand and creating additional consumers for canned seafoods. Men who became acquainted with these products in the Army demanded canned foods on their return home and introduced them among their neighbors.

Our most important fish canning industry, namely salmon, had its beginning during this Civil War period. Salmon is said to have been canned first in Aberdeen, Scotland, in 1824 and it is claimed that the first salmon canned on the American continent was packed at St. Johns, N. B., in 1839 and in Maine shortly after this time. However, it was never packed on an extensive scale as were lobster and oysters. Neither at that time nor since then has the packing of salmon been of any importance on the Atlantic Coast. The industry had its real beginning in California, first became important on the Columbia River and reached full development when salmon canning spread to British Columbia, Alaska, northern Japan and Siberia in the order named.

George and William Hume with their friend A. S. Hapgood were the creators of the Pacific salmon canning industry (Hume, 1904). The Hume brothers, who had worked as fishermen at their home in Maine, went to California as Forty-niners. They noticed that salmon were plentiful in the Sacramento River and believed that money might be made canning the fish. They went back to Maine on a visit, induced A. S. Hapgood, a lobster canner, to return west with them and the first Pacific salmon pack was made at Sacramento, Calif., in 1864. The pack was a failure the next year, but conditions were reported to be extremely favorable on the Columbia River, so the Hume firm moved their equipment to Eagle Cliff, Wash., about 40 miles up the river from Astoria and made the first pack of Columbia River salmon in 1866.

Canned salmon was introduced to England and Germany where the first large market for this product was established by ships loading wheat and lumber for European ports. Canneries became numerous along the Columbia River and as the sale of canned salmon increased steadily the industry sought new and profitable locations, first at New Westminster on the Fraser River in British Columbia in 1867; then at Mukilteo, on Puget Sound, Washington Territory, in 1877; and while Alaska is today the most important salmon canning area, its first cannery was not built until 1878 at Klawak, on Prince of Wales Island.

Salmon is said to have been canned as early as 1877 in northern Japan, but commercial operations date from 1890 in that area (Anonymous, N. D.). The salmon canning industry was established in Siberia about 1906. The largest pack of canned salmon was made in 1936, when production amounted to a world total of 13,720,423 cases of 48 one pound cans.

Sardines were first packed at Nantes, France, in 1834, and by 1860 a fairly good market had been created for French sardines in this country. Efforts were made to establish an American industry in 1871, utilizing young menhaden as raw material. In 1877 Julius Wolff began canning small herring at Eastport, Me., and is credited with starting the first really successful American sardine cannery. In a few years a large number of sardine canners were operating in northern Maine and nearby Canada.

Several efforts were made during the 1890's to establish sardine canning on Puget Sound or in Alaska where large quantities of herring were available, but all of these operations were short-lived. The first successful Pacific Coast sardine cannery was established at San Pedro, Calif., in 1896 (Bitting, 1937). The industry developed slowly until 1917 when the pack was suddenly increased to a large amount by war demands. After the war, production was maintained and increased by extensive cultivation of the export trade. When the depression of the 1930's destroyed the export market, a slump in production occurred but this has been largely overcome by development of the domestic market. The Pacific sardine industry is centered almost entirely in California where it originated. A small pack is canned on the Columbia River and in British Columbia.

Shrimp were first packed in the Gulf of Mexico area. G. W. Dunbar of New Orleans, canned shrimp as early as 1867 but had difficulty with blackening and discoloration. He solved this problem in 1875 with the invention of a can lining which aided greatly in overcoming blackening. Shrimp packing soon became and remains today the principal fishery canning industry of the Gulf coast. Shrimp are also canned on the Atlantic Coast in Florida, Georgia, and South Carolina, but the amount packed on the Atlantic Coast is much smaller than on the Gulf Coast.

While Baltimore was the center of the oyster canning industry for a long period, oysters are packed there today only occasionally. The catch of the Chesapeake Bay region has decreased greatly and the oysters of this area are now more profitably marketed in the fresh state. The greater portion of the oyster pack is now prepared on the Gulf Coast, the industry centering around Biloxi, Miss. The most recent development in the oyster industry is the establishment of oyster canning on the Pacific Coast. The introduction of the Japanese or "Pacific" oyster created a surplus, unmarketable in the raw condition. After several years of experimental work, this oyster was canned commercially in 1931. The pack in that year was 7,930 cases, increasing to 118,853 cases in 1936.

Burnham and Morrill are credited with establishing the first clam cannery in the United States in 1878 at Pine Point, Me. (Stevenson, 1899). The pack of canned clam products was small for some years as considerable difficulty was experienced with discoloration but production slowly increased when this difficulty was overcome. P. F. Halferty developed a method for canning minced razor clams about 1900, building up a commercial clam canning industry in Oregon, Washington and Alaska. The inclusion of minced clams, broth and clam chowder in the list of clam products increased the value of canned clam products until they are now fifth in order of importance of the canned fishery products, thereby displacing oysters.

Crab was first canned in this country by James McMenamin of Norfolk, Va., in 1878. The canning of crab meat has never become important on the Atlantic Coast and the quality of the pack has been variable. The greatest obstacle has been discoloration. In 1936, a method to overcome discoloration was developed by Fellers and Harris and in 1938 Harris packed the common or blue crab of the Atlantic coast commercially. The principal obstacle to a greater development is believed to be the competition offered by imported crab meat.

Canned crab is in considerable demand in the United States but most of the supply originates in Japan. Indeed, this country is the most important market for Japanese canned crab, which is a different species from the common American varieties.

While the crab canning process is said to have been developed in 1892, the Japanese industry was not established on a commercial scale until 1908 (Anonymous, N. D.). Japanese canned crab began to enter the United States markets in appreciable quantities during the World War years, until in 1931 imports amounted to almost double the domestic production of fresh and canned crab meat (U. S. Tariff Commission, 1933).

A domestic crab canning industry has been developed during the past 10 years in Alaska, Oregon and Washington. Processing and other technical difficulties have been overcome and a market has been developed in the Pacific Coast States. It is not believed that the Pacific Coast crab canning industry can be expanded sufficiently to supply the domestic demand for canned crab.

The large supply of groundfish in the North Atlantic has been the basis of numerous attempts to develop a canning industry, which have not been particularly successful because of competition with other canned fishery products or insufficient advertising. Cod and haddock products such as fish flakes, fish cakes or balls and finnan haddie have not found a wide market outside the New England area and are packed on a limited scale. Fish cakes were first packed in Boston in 1878. Finnan haddie (smoked haddock) was first packed about 1890, and a steady but not large demand exists today. Fish flakes, or "salad fish," the flaked meat of cod and haddock, are believed to have been developed by Burnham and Morrill of Portland, Me., in 1898.

At the turn of the century, the industry was experimenting with a variety of products. A number of articles were sold commercially that are not found on the market today such as pickled sturgeon, smoked lake trout, carp, shark meat, menhaden, and a variety of specialty or delicatessen products. Some of these packs did not make a good product, others were not in sufficient demand, while in other instances the cost of raw material became too great for profitable operation. About 1900, the annual pack of canned fishery products was less than half of the amount produced today, and it was thought that production could not be increased greatly or even maintained. The lobster canning industry, once almost exclusively confined to the United States, passed almost entirely over to Canada after 1896. (Cobb, 1919.) While these gloomy predictions were being made the canning industry of fishery products was on the threshold of its greatest development. Production of the standard varieties has been greatly increased and new products have been developed on a considerable scale.

Canned tuna is one of the more recently developed canned fishery products, first packed commercially in 1909. O. W. Lang states:

> According to those who are intimately connected with California fisheries, the packing of tuna had its inception in the Southern California Fish Co. * * * This company, between its date of incorporation in 1892 and until 1905, was interested only in the production and marketing of one-quarter and one-half pound square cans of sardines in oil and the one pound oval pack of the larger sardines. Serious foreign competition, principally from Norway, encroached upon the business, and it was through the resourcefulness and ingenuity of one of its officers that experiments were conducted during 1905, 1906, and 1907 on the canning of tuna. The tests were conducted under the direction of Mr. Lapham, the president, with Wilbur F. Wood and James McMann as the active investigators. Their source of raw material was albacore, which when cooked, they all agreed, resembled chicken in taste and flavor. This characteristic flavor, no doubt, added impetus to their experiments, but it was not until 1907 that their efforts were rewarded. * * *
>
> * * * The first successful pack was produced in 1909 when 2,000 cases were packed which were marketed by Sigmund Seeman, Seeman Brothers, New York.

Mackerel was canned in small quantities in New England as early as 1843. The introduction of mackerel into the general canned food market occurred in 1927 when George Ogawa put up a pack of 10,725 cases of California mackerel "salmon style" which was sold at a price to compete with the cheaper varieties of salmon. Production of Pacific mackerel increased to 388,500 cases in 1928, and rapidly reached a peak of 1,795,700 cases of 48 one-pound cans in 1935.

The most recently developed canned fishery product is not intended for human consumption, but is prepared for feeding pets and fur animals and for use in fish hatcheries. In 1938, 413,434 cases of pet food made from fishery products were packed. Production is divided between California, where mackerel or whale meat is utilized as the basic ingredient, and in New England where pet food is a byproduct in the packing of fish fillets.

Are there possibilities of further expansion in the fish canning industry? Yes, if world trade conditions improve, and the products are scientifically developed and properly marketed. New products may be marketed profitably only if the canner has a grasp of the required technical data, operates on an economical basis, and the article is of acceptable quality and can compete successfully with established products on the market.

STATISTICS ON PRODUCTION OF CANNED FISHERY PRODUCTS

The canning of fishery products is the most important factor in the fishery industry today; indeed, canned fish and fishery products hold an important place in the general food canning industry, exceeding canned meat and meat products both in quantity packed and value to the packer. The total market value of all fish and fishery products to primary handlers in 1938 was estimated at about $214,000,000 (Fiedler, 1939). The fish canning industry accounted for $83,446,000, or 39 percent of this total.

About 160 species of fish are utilized regularly for food in the United States. Fifteen are canned regularly on a large commercial scale. while a number of others are packed occasionally or in quantities too small to merit separate record in statistical reports. The record domestic pack of canned fishery products was produced in 1936 and amounted to 794,707,014 lbs., valued at $94,564,254.

Salmon is the most important canned fishery product, its value in 1938 amounting to 50.8 percent of the total value of all canned fishery products. Next in importance are tuna and tunalike fishes, sardines, shrimp, clam products, mackerel, and oysters, in the order named. The seven varieties listed above account for 96 percent of the value of the total pack. While canned sardines ranked second in value in 1929 and oysters fifth, these products had dropped to third and seventh places, respectively, in 1938.

NUMBER OF PLANTS AND DISTRIBUTION ACCORDING TO PRODUCTS

A total of 382 food packing establishments was engaged in canning fishery products in the United States and Alaska during the year 1938. In comparison with 1929, this represents a decrease of 23 percent; 497 canneries were reported in operation that year. The data presented in table 1 show that 33 percent of the canneries were engaged in packing salmon, 16 percent packed clam products, 15 percent sardines, and 13 percent packed shrimp.

TABLE 1.—*Canned fishery products of the United States and Alaska, 1938.*

[Summary of production by commodities]

Product	Number of plants	Standard cases	Pounds	Value
Salmon				
United States	27	472,721	22,690,608	$ 5,728,892
Alaska	98	6,806,998	326,735,904	36,636,897
Sardines:				
Maine	25	671,635	16,790,875	2,367,045
California	31	2,261,678	108,560,544	7,102,358
Tuna and tunalike fishes	20	2,754,143	66,099,432	15,183,636
Mackerel	24	965,629	46,350,192	2,896,220
Alewives	10	52,826	2,535,648	143,558
Alewife roe	29	37,641	1,806,768	165,711
Shad	8	10,845	520,560	29,950
Shad roe	10	3,015	144,720	95,909
Cat and dog food	9	413,434	19,844,832	888,399
Fish flakes	4	45,721	2,194,608	291,426
Finnan haddie	3	488	23,424	7,518
Fish cakes, balls, etc.	6	97,263	4,668,624	665,307
Fish paste	3	3,987	191,376	143,147
Sturgeon caviar	4	2,491	119,568	307,298
Whitefish roe and caviar	5	1,052	50,496	36,478
Salmon roe and caviar (for food)	4	1,563	75,024	28,077
Salmon eggs (for bait)	8	4,656	223,488	85,348
Miscellaneous fish and roe	14	19,792	950,016	182,729
Clam products	60	[1]769,665	19,312,005	3,189,628
Oysters	42	482,441	7,236,615	1,886,476
Shrimp	50	1,077,003	18,113,297	4,872,393
Crabs	21	13,699	657,552	260,134
Turtle products	4	7,410	355,680	80,869
Miscellaneous shellfish	14	26,583	1,275,984	170,486
Total	[2]382	17,004,379	667,527,840	83,445,889

[1] "Cut-out" or "drained" weights of can contents are included for whole or minced clams and gross can contents for other clam products.
[2] Exclusive of duplication.

GEOGRAPHICAL DISTRIBUTION OF THE INDUSTRY

During 1938, fishery products were canned in 22 states and Alaska. Alaska alone accounted for 44 percent of the total value of the pack in that year, while the Pacific Coast States of Washington, Oregon and California accounted for 40 percent. Therefore, the Pacific Coast including Alaska contributed 84 percent in value of the total pack of canned fishery products in the United States. The New England and Gulf Areas were about equal in importance, each accounting for 6 and 8 percent, respectively, of the total value of the pack. Most of the remainder was canned in the Middle and South Atlantic States, with a small amount of specialty products packed in the Great Lakes Area.

Alaska ranked first in value of canned products because of its productive salmon fishery. California was second with 30 percent due to its sardine, tuna and mackerel fisheries. Washington, with 5 percent, was in third place, owing its rank largely to salmon, clam and oyster products. Oregon and Maine each accounted for 4 percent, the first because of its production of salmon and albacore, the latter due to its important sardine industry.

The geographical distribution of the fish canning industry in Canada parallels that of the United States in that the industry is centered on the Pacific Coast. The total value of the pack in

Canada in 1938 amounted to $16,297,611. In that year British Columbia, the only province of Canada bordering on the Pacific, was credited with $12,747,172 of the value of the production of canned fish and shellfish, or 78 percent of the total. Salmon accounted for $12,267,465 or 96 percent of this amount. British Columbia is exceeded only by Alaska in the canning of salmon on this continent.

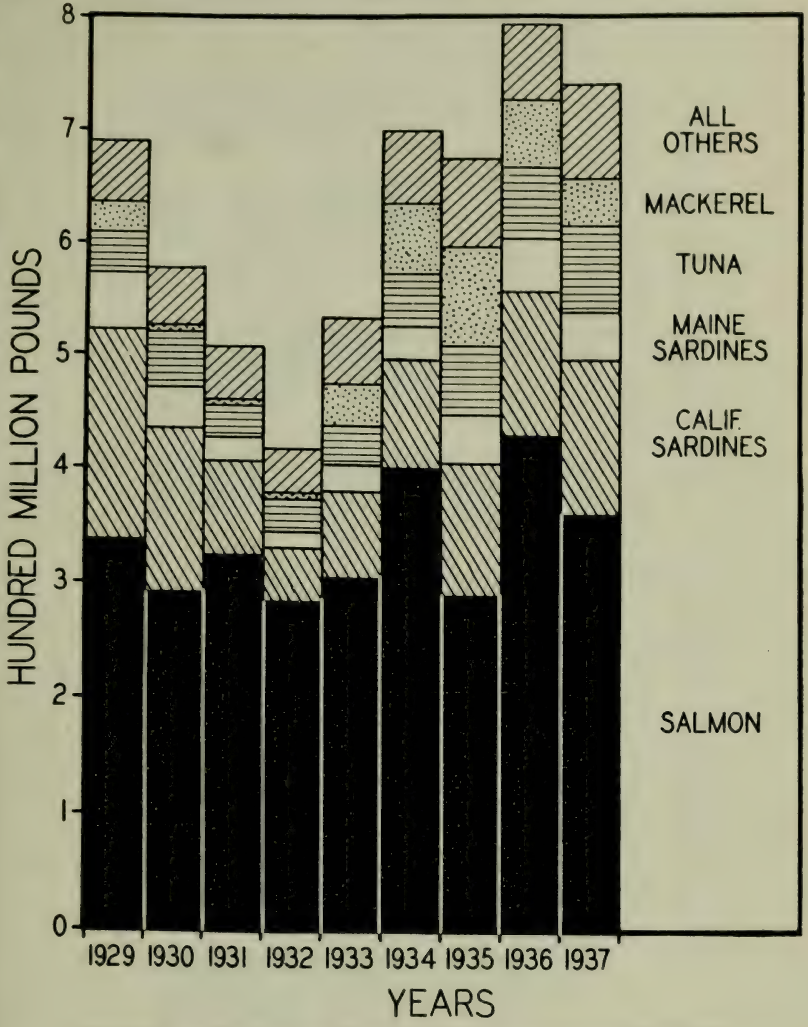

FIGURE 1.—Production of canned fishery products 1929-1937.

Detailed statistical data on the fish-canning industry in the United States are given in Tables 1, 2 and 3. Figure 1 illustrates graphically the production of the more important species utilized by canning, and a comparison of the quantity canned in various years.

TABLE 2.—*Pack of canned fishery products in the United States and Alaska, 1921 to 1938*

[Standard cases]

Year	Salmon						Sardines			
	Pacific Coast States		Alaska		Total		*Maine and Massachusetts*		*California*	
	Cases	*Value*	*Cases*	*Value*	*Cases*	*Value*	*Cases*	*Value*	*Cases*	*Value*
1921	1,002,948	$ 9,234,425	2,596,826	$19,632,744	3,599,774	$28,867,169	1,399,507	$3,960,916	398,668	$ 2,346,446
1922	733,246	8,633,524	4,501,652	29,787,193	5,234,898	38,420,717	1,869,719	5,750,109	715,364	3,361,480
1923	1,367,263	12,660,566	5,035,697	32,873,007	6,402,960	45,533,573	1,272,277	5,288,865	1,100,162	4,607,931
1924	958,662	9,394,467	5,294,915	33,007,135	6,253,577	42,401,602	1,899,925	7,191,026	1,367,139	5,445,573
1925	1,558,613	15,379,976	4,459,937	31,989,531	6,018,550	47,369,507	1,870,786	6,716,701	1,714,913	6,380,617
1926	835,738	10,139,302	6,652,882	46,080,004	7,488,620	56,219,306	1,717,537	6,727,388	2,093,278	7,807,404
1927	1,504,451	15,712,497	3,572,128	30,016,264	5,076,579	45,728,761	1,262,124	5,249,030	2,563,146	9,268,784
1928	842,903	9,254,258	6,083,903	45,383,885	6,926,806	54,638,143	2,055,763	8,076,546	2,771,527	9,658,822
1929	1,620,523	15,616,312	5,370,159	40,469,385	6,990,682	56,085,697	2,025,801	6,897,946	3,831,215	11,996,997
1930	1,054,001	13,140,081	5,032,478	29,695,872	6,086,479	42,835,953	1,399,212	4,459,071	2,979,333	8,741,928
1931	1,336,234	8,986,308	5,403,811	29,096,868	6,740,045	38,083,176	885,408	2,647,187	1,713,407	4,715,089
1932	654,460	4,744,162	5,254,509	21,715,918	5,908,969	26,460,080	545,697	1,370,050	953,981	2,358,399
1933	1,136,861	7,865,903	5,225,604	28,376,014	6,362,465	36,241,917	980,906	2,397,348	1,539,446	3,805,168
1934	901,206	8,205,947	7,481,830	37,611,950	8,383,036	45,817,897	1,142,730	3,315,190	1,970,047	5,481,391
1935	894,768	6,707,130	5,133,122	25,768,136	6,027,890	32,475,266	1,655,839	5,142,750	2,420,055	6,237,262
1936	527,574	5,309,438	8,437,603	44,751,633	8,965,177	50,061,071	1,845,860	5,740,454	2,616,530	7,302,273
1937	885,372	8,386,165	6,669,665	44,547,769	7,555,037	52,933,934	1,680,241	4,998,373	2,812,456	8,592,117
1938	472,721	5,728,892	6,806,998	36,636,897	7,279,719	42,365,789	671,635	2,367,045	2,261,678	7,102,358

TABLE 2.—*Pack of canned fishery products in the United States and Alaska, 1921 to 1938*—Continued

Year	Tuna and tunalike fishes		*Oysters*		*Shrimp*		*Clam products*	
	Cases	*Value*	*Cases*	*Value*	*Cases*	*Value*	*Cases*	*Value*
1921	549,150	$ 3,074,626	442,086	$2,179,271	655,364	$3,804,781	(1)	$1,166,507
1922	672,321	4,511,873	505,973	2,423,616	579,797	3,064,087	(1)	1,716,365
1923	817,836	6,914,760	524,544	2,720,073	700,429	4,381,534	(1)	1,710,616
1924	652,416	5,756,586	447,481	2,478,044	718,517	4,608,950	(1)	2,161,389
1925	1,102,471	8,499,080	654,755	3,721,159	735,714	3,782,819	(1)	1,850,378
1926	851,199	5,282,283	413,834	2,026,569	732,365	4,122,092	(1)	2,004,650
1927	1,255,818	8,368,227	447,297	2,367,949	852,764	5,321,652	525,286	2,744,954
1928	1,216,222	8,374,030	503,952	2,760,576	851,831	5,181,547	531,640	2,623,598
1929	1,504,306	9,873,453	519,145	2,732,478	909,949	5,528,792	554,639	2,548,472
1930	2,010,640	13,055,876	396,174	1,836,862	818,491	4,960,542	558,884	2,666,045
1931	1,216,976	7,279,392	306,278	963,525	821,375	3,982,247	500,040	2,256,909
1932	1,206,177	6,183,019	392,664	1,007,624	758,106	2,594,980	371,288	1,797,002
1933	1,443,133	6,934,485	348,130	1,076,318	860,462	3,479,477	434,500	1,766,406
1934	1,966,943	10,009,542	438,542	1,871,060	1,021,822	4,403,077	633,055	2,713,228
1935	2,510,828	12,823,729	500,885	2,044,903	1,086,345	4,721,872	666,981	2,680,935
1936	2,680,734	14,715,391	528,705	2,180,869	917,440	4,672,198	754,334	2,976,297
1937	3,144,501	18,995,779	708,950	2,932,681	1,286,406	7,130,747	773,448	3,013,446
1938	2,754,143	15,183,636	482,441	1,886,476	1,077,003	4,872,393	769,665	3,189,628

TABLE 2.—*Pack of canned fishery products in the United States and Alaska, 1921 to 1938*—Continued

Year	Miscellaneous fishery products								Grand total
	Fish roe, caviar and eggs		Other fish		Other shellfish		Total		
	Cases	*Value*	*Cases*	*Value*	*Cases*	*Value*	*Cases*	*Value*	*Value*
1921	(1)	(1)	(1)	(1)	(1)	(1)	(1)	$1,234,990	$ 46,634,706
1922	(1)	(1)	(1)	(1)	(1)	(1)	(1)	1,216,700	60,464,947
1923	(1)	(1)	(1)	(1)	(1)	(1)	(1)	1,287,853	72,445,205
1924	(1)	(1)	(1)	(1)	(1)	(1)	(1)	2,121,419	72,164,589
1925	(1)	(1)	(1)	(1)	(1)	(1)	(1)	2,256,877	80,577,138
1926	(1)	(1)	(1)	(1)	(1)	(1)	(1)	2,003,548	86,193,240
1927	57,586	$ 477,415	236,579	$1,765,888	4,479	$ 91,473	298,644	2,334,776	81,384,133
1928	78,394	681,150	683,255	3,703,918	10,590	173,525	772,239	4,558,593	95,871,855
1929	46,501	502,040	913,088	4,684,879	14,912	214,301	974,501	5,401,220	101,065,055
1930	92,478	1,619,624	402,656	2,399,886	22,839	282,474	517,973	4,301,984	82,858,261
1931	50,871	1,021,701	329,883	1,829,195	16,543	170,370	397,297	3,021,266	62,948,791
1932	39,374	635,720	307,103	1,174,401	11,247	167,907	357,724	1,978,028	43,749,182
1933	42,912	635,549	1,074,524	3,148,941	30,490	314,354	1,147,926	4,098,844	59,799,963
1934	46,852	821,528	1,722,160	5,115,092	53,715	473,337	1,822,727	6,409,957	80,021,342
1935	61,413	960,349	2,446,054	7,464,287	58,786	447,681	2,566,253	8,872,317	74,999,034
1936	59,040	1,028,293	1,669,631	5,434,760	60,525	452,648	1,789,196	6,915,701	94,564,254
1937	69,974	996,169	1,440,597	4,995,890	59,199	585,799	1,569,770	6,577,858	105,174,935
1938	61,337	786,441	1,599,066	5,180,634	47,692	511,489	1,708,095	6,478,564	83,445,889

[1] Not enumerated separately prior to 1927.

Note: "Standard cases" of salmon, California sardines, fish roe, caviar and eggs, other fish, and other shellfish represent the various sized cases converted to the equivalent of forty-eight 1-pound cans; Maine sardines, one hundred ¼-pound cans to the case; tuna and tunalike fishes, forty-eight ½-pound cans to the case; oysters, forty-eight 5-ounce cans to the case; shrimp, forty-eight 5-ounce cans to the case in the dry pack and forty-eight 5¾-ounce cans to the case in the wetpack; and clam products forty-eight No. 1 cans to the case.

TABLE 3.—*Canned fishery products of the United States and Alaska, 1938*

[Value of production by States]

State	Canned products
Maine	$ 3,319,212
Massachusetts Rhode Island	1,354,127
New York	561,267
New Jersey Pennsylvania	1,215,126
Delaware Maryland	506,476
Virginia	104,502
North Carolina	65,028
South Carolina	312,208
Georgia	743,663
Florida	347,914
Alabama and Mississippi	1,917,637
Louisiana	2,776,572
Texas, Illinois and Wisconsin	525,928
Washington	3,762,575
Oregon	3,638,815
California	25,232,688
Alaska	37,059,151
Total	83,445,889

PRINCIPLES INVOLVED IN CANNING SEAFOODS

THE RELATION OF MICRO-ORGANISMS TO CANNING

The canning of fishery products in hermetically sealed, heat-sterilized containers has for its objective the prevention of spoilage through micro-biological action. Fresh, dried, salted or smoked fishery products may be rendered unfit for use by a wide variety of causes, but to protect canned fishery products careful consideration must be given to micro-organisms which are the cause of putrefaction or spoilage under ordinary circumstances.

Micro-organisms, as the name indicates, are a class of living things too small to be seen except by the aid of a high powered microscope. They are unicellular; that is, each life cell is a separate and complete organism, though they may be joined in chains or masses. Micro-organisms are intermediate between plant and animal life, some almost plants, other animals (Marshall, 1921). They are divided into three general groups: yeasts, molds and bacteria.

In this study, consideration has been given only to that class of micro-organisms generally classified as bacteria. Yeasts and molds are destroyed at temperatures much below those required for commercial sterilization. The presence of yeasts and molds in canned fishery products indicates either gross under-sterilization or defective containers.

These bacterial organisms are distributed almost everywhere in air, soil and water. Bacteria may lodge on fish while they are alive and in the water, or during the period after they have been removed from the water and before they have been packed in hermetically sealed containers. A large number of species of bacteria may therefore be concerned in spoilage through decomposition.

Micro-organisms require moisture and a favorable temperature for development because they can utilize only liquid food which is absorbed through the cell wall. A moisture content of less than 35 percent has a direct inhibiting effect. The most favorable temperature for the development of ordinary forms of bacteria is between 70° and 100° F. Live fish are able to resist the growth of these organisms and their temperature is unfavorable to rapid multiplication. After death, however, there is no longer any resistance to growth of micro–organisms, and the temperature of the body tissue rises rapidly. Conditions are then favorable and the micro–organisms on the fish grow and multiply rapidly.

The body tissues must be liquified so that micro–organisms may absorb the food necessary for growth and multiplication. These organisms throw out secretions known as enzymes which have the property of breaking down, decomposing, or liquifying the surrounding tissue so that this material may be absorbed through their body walls. Waste products resulting from this absorption are excreted through the cell wall, thus furnishing such distinguishing characteristics of decomposition as "off" odors and tissue breakdown. This process is known as putrefaction.

The cells in animal tissue also contain enzymes which do not cease their activity upon the death of the animal but may digest the cells in which they are contained. This process is known as autolysis or self–digestion and is distinct from putrefaction as described in the preceding paragraph. Autolysis is especially marked in species which have been feeding when caught. Death prevents completion of the normal cycle of digestion. The large quantities of digestive enzymes manufactured during the feeding process are prevented from fulfilling their function of preparing the food for absorption and attack the walls of the digestive tract, which are destroyed with extreme rapidity, and the enzymes then pass to the flesh which is also softened in a short time. This process is normal and the flesh is not absolutely inedible, but is unsuitable as raw material for canning due to the extreme softness of texture.

A good example of autolysis for purpose of illustration is in "feedy" salmon. Troll-caught salmon must be eviscerated immediately after catching and packed in crushed ice. If this is not done they will be found unfit for use in a very few hours. The flesh will become soft and flabby; the abdominal surface to such a degree that the bones protrude. Though the flesh is not putrefied, it is difficult to handle in canning and the resultant product is objectionable in appearance, color, and texture.

The fundamental principle of canning is the application of heat to food in hermetically sealed containers at a temperature and for a period of time sufficient to destroy any yeasts, molds and enzymes, and to destroy or render inactive any bacterial organisms likely to cause spoilage.

Space does not permit discussion of the various organisms encountered in the preparation of canned fishery products, except very generally and briefly. Heat–resistant, spore–forming organisms are the most important types and the heat treatment or process must be sufficient to render them impotent. A short heat treatment at a high temperature or a long heat treatment at a lower temperature of about 212° F. may destroy the active or vegetative organism but leave the spores unharmed. These forms may return to activity under favorable conditions even after a long dormant period.

The spore–formers are either aerobes or anaerobes. The aerobes require oxygen to develop. If the can has been properly exhausted, that is, if a sufficient vacuum has been obtained, the aerobic bacteria will lie dormant until the processed container is opened and there is little likelihood of spoilage in the sealed container. The presence of aerobic spore–formers in a properly sealed container containing a sufficient vacuum indicates insufficient heating but it does not necessarily follow that the product is unfit for food. Until very recently the great majority of all home canned products were probably so infected.

On the other hand the anaerobic organism requires the absence of oxygen to develop and multiply. If anaerobic bacteria are present, a complete seal of the container and a sufficient vacuum only make conditions favorable for their development unless the spores are destroyed by heat in canning. Spoilage from this cause is usually indicated by swelled or bulging can ends, accompanied by an extremely pervasive and offensive odor when the can is opened. Spoilage may occur without gas formation and bulged ends, if certain types of anaerobic organisms are present. Such cans are known as "flat sours."

STERILIZATION

Sterilization, in the literal sense of the word, means the absolute destruction of all organisms present, and the maintenance of that condition. The heat treatment of foods in canning is commonly called sterilization but if the word is to be construed strictly this is not correct. Commercial packers use the term "processing" which is more nearly accurate as only those organisms likely to cause spoilage under commercial conditions of manufacture and storage are destroyed.

Theoretically, complete sterilization is possible and desirable, but actually there are many factors affecting the cooking process in canning, which work against the attainment of this ideal. Processing is used in canning for reasons other than sterilization or destruction of organisms causing spoilage. In certain products the texture, in others appearance, while in still others the flavor is improved. However, if processing is carried out at too high a temperature or for too long a period of time it may also seriously damage the quality of a product, by causing excessive softening of the texture, affecting the appearance through darkening or discoloration, or the taste through scorched or overcooked flavors.

To be effective a process not only must preserve a product but also must operate within certain limits. A temperature sufficient to destroy spoilage organisms establishes the minimum temperature and time, or lower limit of heating, while quality considerations determine the maximum, or upper limit of processing.

Adequacy of process varies with individual products and depends on a number of factors, the most important of which will be discussed.

CONDITION OF RAW MATERIAL

The first and most important consideration in sterilization processes is the condition of the raw material. It is useless to expect the process of heat sterilization to produce a sound, marketable article from inferior or partly-decomposed raw material. Processes are worked out on the basis of the use of fresh raw material in such condition so as to result in a finished article of good edible quality. Variations in the quality of raw material affect the value and adequacy of the process.

FRESHNESS

Due to the great numbers of micro-organisms present in stale or decomposing flesh, sterilization is more difficult than for products that are canned while fresh. It has been proved that the greater the number of micro-organisms present, and the greater the degree of concentration, the longer the time required to destroy them at a given temperature. Individual bacteria do not all die at once as soon as the temperature of the surrounding medium has reached the "death" point. For instance, a process which might be sufficient for preservation, if only a normal surface contamination were encountered as in fresh fish, may reduce greatly but not inhibit entirely a heavy infection of spoilage organisms penetrating the flesh, as when the fish are stale. This condition then necessitates a heavier process, and even then, though the product may be sterile, the odor and flavor of staleness persist. No matter how heavy the process they cannot be removed.

Commercial canners, with rare exceptions, do not today knowingly pack fish which are not fresh. In the past, fish have been handled too much or carelessly, packed too deeply in the holds of fish boats, transported too far or held too long. Raw material receiving such treatment usually is heavily infected with spoilage organisms so that the incidence of decomposition is hastened. Every effort is now made by the industry to regulate conditions of handling and transport.

In spite of this care, during some seasons spoilage has occurred in portions of certain packs. It has been found in those instances that the rigid observance of a fixed set of precautions was followed to the neglect of variables which might affect the value of fixed rules. For example, in some instances where spoilage has occurred, when fish were canned within a short time after capture, investigation has determined that the weather was unusually warm, shortening the time interval in which fish might safely be canned. The canner must watch such variables as temperature and humidity, in making or interpreting regulations for the handling and canning of raw material.

MATURITY

In the canning of fruits and vegetables the degree of ripeness, which is known as maturity, increases the difficulties of sterilization. For example, the starch content in overripe vegetables such as peas is greatly increased, retarding heat penetration. Overripe fruit softens to form a more compact mass which is more difficult to sterilize than fruit with a firm texture. The maturity problem also is encountered in canning fishery products, especially salmon, shad, alewives and oysters. Maturity in fish is associated with the physiological changes of approaching spawning. A softening of the texture of the flesh, which favors increased growth of microorganisms, occurs when spawning is far advanced. In some species in a spawning condition, ammonia and sulphur compounds in the flesh are more likely to react with the tin plate, thus leading to discoloration of the product or container during processing or later during storage.

Fish such as salmon, canned when in a spawning condition, result in a product with "woody" flavor and a rather unpleasant "grassy" odor, which, however, are not an indication of decomposition. The skin is unusually thick and "water marked," showing the striking calico marking typical of spawning condition in the Pacific salmons. Such raw material must be especially well exhausted and processed in order to improve the odor and flavor. Even then, the product is not of standard quality although it is edible.

FILL OF CONTAINER

Variations from standards in fill of the container, followed as the best practice, may affect sterilization and give rise to certain difficulties.

HEAT PENETRATION

When the container is overfilled there is a greater mass to be brought to required temperature; therefore, the processing used may be insufficient. An overfill of solid material compresses the mass and decreases the rate of heat penetration by hindering possible convection currents. "Packing" or compressing might occur to such a degree that heat would penetrate by conduction alone. This is illustrated most clearly in the canning of certain vegetables, but the condition may occur in the canning of fishery products.

VACUUM

Overfilling not only retards heat penetration but also may reduce the amount of vacuum since it varies inversely with the volume of the headspace at the time of sealing, other factors being equal. Such cans may become "springers" and therefore are unmarketable. While spoilage has not occurred, the external evidence is to the contrary and the buyer very wisely rejects such containers.

"CUT-OUT" WEIGHT

Regulations of the U. S. Food and Drug Administration require certain minimum "cut–out" weights for most varieties of canned seafoods and for many other canned products as well. Government inspectors check these packs at intervals, and any portion below the required "cut–out" weight may be seized if it goes into interstate commerce. "Cut–out" weight is the drained weight of the product, exclusive of brine or other liquid, after a specified period of draining, usually 1 to 2 minutes on a screen of ⅛-inch mesh. Naturally, the fill of the can is the most important factor in maintaining the required "cut–out" weight. Canneries that pack oysters, clams and similar products which are affected by maturity, shrinkage or other factors causing variation in the amount of solids in the canned products must change their fill–in weights at weekly, daily or sometimes even more frequent intervals to keep the "cut–out" weight at the required amount. Over–processing will cause extra and excessive shrinkage in such products. Therefore, the sterilization process must be sufficient, yet hold shrinkage to a minimum. The danger is that the process may be so reduced that the product is under–sterilized.

CORROSION

In many products the amount of fill of the can is important in its relation to corrosion of the tin plate. The great advance in mechanical exhaust or vacuum sealing methods has been forced partly by corrosion difficulties. Air in the can should be eliminated as much as possible because the presence of oxygen accelerates corrosion. In underfilled cans, then, there is greater opportunity for corrosion. Underfilling or "slack filling" is sometimes resorted to in attempts to reduce the process. This practice is a mistake because it is not effective and only increases the possibility of corrosion in the headspace of the can (National Canners Association, 1939).

STRAIN ON CONTAINERS

If the container is overfilled, especially with solid material such as salmon or shad or in using containers of the larger sizes, the seams of the can may be strained by physical expansion of the product during processing, leading to spoilage of the product through infection from outside.

CONSISTENCY OF PRODUCT

STARCH CONTENT

It has long been known that starchy foods have a very slow rate of heat penetration. Fishery products such as fish balls, fish pudding and fish pastes must be processed for longer periods than fish which are canned without added starchy ingredients. For example, fish pudding will require a process averaging 5 minutes longer than mackerel or salmon solely because of starch content, even though the size of can, fill, initial temperature and all other factors show no difference between the products.

A product packed too tightly heats much more slowly than a more loosely packed can of the same product. This is indicated most clearly in the canning of certain vegetables, but the condition may occur in the canning of fishery products. A too heavy consistency will of itself delay the rate of heat penetration.

SIZE OF PARTICLES

The size of the particles into which a product is divided has considerable effect on the rate of heat penetration. For example, shrimp will heat through to the center more rapidly than salmon because a can of shrimp contains a large number of small pieces and salmon one or two large pieces.

COMPOSITION OF CONTAINER

Tin, or rather tin plate, which is about 98.5-percent steel base (iron) and 1.5-percent tin, and glass are the two principal materials used as containers of processed foods. Steel or iron is a much better conductor of heat than glass, while water, an important element in the composition of fishery products, is the poorest of the three unless there is a free flow of convection currents.

CONDUCTION

The power of conduction of any material is expressed in terms of "diffusivity." This term may be defined as the temperature change produced in a unit cube of material in a unit time by a unit quantity of heat conducted across a unit area of the product per unit difference in temperature. Diffusivity is a constant for any given material, and equals 10.8 for iron, 0.37 for glass, and 0.084 for water.

Water, when convection currents are absent, is thus the poorest conductor of heat of the three media mentioned. In terms of diffusivity, the heat conduction of glass is 4.5 times as rapid as that of water. Heat conduction through tin plate is approximately 30 times as rapid as through glass and 130 times as rapidly as through water. Iron heats only from 4 to 8 times more rapidly than water when convection currents in the water are unhindered, and in such case water in glass containers heats approximately as rapidly as the conducting power of the glass. To summarize, if the conductivity of the container is less than that of the product, the container is the limiting factor to the flow of heat and vice versa.

THICKNESS OF CONTAINER WALLS

If two containers, with different wall thicknesses but of the same size and material are heated, the rate of heat penetration will vary according to the thickness of the container wall. Glass containers, in addition to possessing a lower heat conducting factor, have much thicker walls than containers of tin plate. Additional processing time is required for an equivalent amount of material if it is packed in glass rather than in tin plate.

SIZE OF CONTAINER

The size of the container is an important factor in sterilizatio due to the surface–volume relationship. In the smaller sizes o cans the amount of surface per unit of container volume expose to processing temperature is greater than that of larger size. Fo example, a No. 1 eastern-oyster can has a surface of 45 squar inches and a volume of 19.5 cubic inches. Thus the ratio of sur face to volume $\frac{s}{v}$ equals 2.3. A No. 10 can, the largest siz commonly used in packing processed or canned foods has a surfac of 196 square inches and a volume of 191 cubic inches. The sur face–volume relationship in this case is 1.03.

The distance from the surface to the center of the can als affects the rate of heat penetration. Odd–shaped cans such as th "quarter square" used in canning sardines have a short surface–to center distance as compared with the volume of the can. A spherical can would have the greatest distance from surface to center for a given volume.

In cans of similar shape, (the height must be greater than the diameter), such as the No. 1 or No. 2 cans, it has been found that the time required for the heat to penetrate to the centers of the cans varies approximately as the squares of their radii, with convection currents absent. Thus, in a No. 2 can the radius squared equals 2.96 inches and in a No. 10 can it is 9.60 inches. If a No. 2 can of clam chowder required a processing time of 60 minutes to reach a center temperature of 240°F., and it is desired to determine the time required for a No. 10 can, the following calculation would be used: 2.96:9.60::60:X = 194 minutes.

INITIAL TEMPERATURE

Delay between exhausting or hot filling and processing causes a lowering of the initial temperature, which should be avoided. If the cans are sealed hot they may lose their original high initial temperature by delay before processing, but they would not lose the other principal benefit of a heat exhaust, namely, a good vacuum.

Vacuum sealing or mechanical exhaust has displaced heat exhaust in the greater portion of the seafood-canning industry. In the packing of such products as salmon and tuna, this means that the initial temperature is much lower than with exhaust by heat, and that processes based on heat exhaustion are no longer valid. Therefore, an allowance must be made for a lower initial temperature in sterilization procedures, where the product is exhausted mechanically. A low initial temperature requires a longer sterilization period. A miscalculation of the initial temperature may result in under–processing.

"COMING-UP" TIME

In the more easily sterilized products such as wet–pack shrimp, in which a slight over–cooking brings about a serious deterioration in quality, the heating received during the "coming-up" period must be considered carefully. Delay in bringing to retort temperature or the use of a longer coming-up time than usual may result in the over–cooking of products with a narrow range between the upper and lower limits of processing.

RETORT TEMPERATURE

Theoretically, it is desirable to use the highest possible retort temperature because of the greater temperature gradient between retort and can. If products of like nature and having the same initial temperature are processed in two different retorts, one at 240° F. and the other at 250° F., each will reach the temperature of the retort in which it is being processed in the same length of time. However, cans in a retort at 250° F. will approach a temperature of 240° F. in a much shorter time than cans in the retort held at 240° F. and will hold that temperature over a greater period of time. Where there is likelihood of discoloration or a "scorched" flavor, it is preferable to use the higher retort temperature in actual practice, as the use of higher retort temperatures shortens the time of processing, and length of processing appears to more seriously affect quality than temperature of processing.

MODE OF HEAT TRANSFER

Heat from the processing medium, steam, water or air, enters the can or other container by one of two means: Conduction or convection.

CONDUCTION

Conduction may be defined as the transfer of heat between adjacent stationary molecules, that is, the heat must pass from one solid particle to the next. Therefore, heating is slow and gradual. For example, an iron bar heats along its length by conduction so that one end may be quite hot, while the other is still cool. Dry-pack shrimp, fish pastes and fish cakes are examples of canned fishery products which are heated mainly by conduction. Such processes are longer and the product is more likely to spoil unless the sterilization process is closely watched and carefully worked out.

CONVECTION

Convection may be defined as the transfer of heat by currents. A pail of water heats mainly through convection, since water or other liquids tend to expand when they are heated, which decreases the density. The greater density of the colder liquid causes the heated liquid to rise and set up a circulation, thus distributing the heat throughout the mass. Transfer of heat by convection is very much faster than transfer of heat by conduction. Wet–pack shrimp, oysters and "ready–to–serve" soups and chowders are products heated mainly by convection. Products in which convection currents are sluggish or absent due to a semi–solid nature of the product, such as salmon, require much longer processing at a given temperature than products in brine or liquid in which convection currents are unhindered.

TIME AND TEMPERATURE RELATIONSHIPS

In sterilization procedures, time and temperature are inseparable. From a study of the death rates of heat–resistant organisms, sterilization was found to be 100 times more rapid at 250° F. than at 212° F. Therefore, time is essential and must be considered equally with temperature when specifying sterilization temperatures.

A lower temperature applied for a longer period of time may give a sterilizing value equal to that of a higher temperature applied for a shorter time. This relationship of time and temperature gives rise to various combinations of time periods and temperatures which are of equivalent sterilizing values. For example, sardines in California have been processed for the following times and temperatures: 70 minutes at 252° F., 80 minutes at 244° F., 85 minutes at 241° F., and 90 minutes at 240° F.

A short process at a high temperature has certain advantages; for instance, more "cooks" per day per retort, thereby increasing the capacity of the plant. Also, there is greater uniformity of sterilizing value between individual cans. Difference in sterilizing value between cans may be due to a number of factors which were discussed previously, such as variation in fill or initial temperature, but high temperatures in sterilization tend to eliminate these differences. However, short high-temperature processing cannot be applied to some products without injuring color or flavor. For example, minced razor clams, when processed at a temperature of 240° F. or higher, not only have an inferior color and flavor but undergo a greater loss by shrinkage. The added oil in sardines processed at high temperatures is said to exert a severe dissolving effect on the rubber-compound gaskets in the end-seams of the cans. Can sizes and methods of cooling as well as the nature of the product also influence the selection of process time and temperature.

WATER IN THE RETORT

The presence of water in the retort has no effect as far as sterilization is concerned, since the temperature of water in a retort is the same as that of steam. The time required to bring a retort to processing temperature will be longer as the heat absorbing capacity of water is great. If any considerable amount of water is present in a retort, the product may be affected in other ways. Water in contact with lithographed cans tends to shake them about and the resultant abrasion scratches (water marks or blisters) the lithographing. Fading of the inks may also take place. If hard water is used in a retort, the corrosive effect on tin cans is very evident, especially if aided by agitation during processing. A small amount of water in the retort is essential to prevent the formation of a sudden vacuum upon the entrance of water, when water is used for cooling.

AIR IN THE RETORT

The presence of air in a retort during processing is a potential danger, due to the possibility of non–uniform temperature distribution. Air may be present in a retort unintentionally through insufficient venting, or intentionally as in a steam and air mixture process, such as that which has been used for the processing of packs in glass containers. In a steam–and–air process where there may be no venting, violent agitation of the gases is the only way to secure uniform temperature in the retort, and this agitation is difficult to secure and maintain in a retort filled with cans or glass jars. In some retorts of the steam–and–air type, the air is preheated to the temperature of the steam in an effort to gain more perfect mixing and more uniform temperature distribution.

Where there is a variation in temperature within the retort and the cans have been sufficiently sterilized, there is apt to be a difference in quality in the pack due to the different amount of heat received by cans in different parts of the retort. This condition may lead to the under–sterilization of some of the containers. The positions at which thermometers are to be located should be determined very carefully in deciding on processes requiring a mixture of air and steam.

In a mixture of steam and air there are certain factors that tend to prevent a uniform mixture, which of course is essential to uniform temperature distribution.

DALTON'S LAW

Where two gases occupy the same volume the pressure of the mixture is equal to the sum of the components. This is the well-known principle of physics called "Dalton's law." The share each gas exerts in the total pressure is called its "partial pressure." Thus in a retort, the partial pressure exerted by the expansion of imprisoned air is additive to the pressure of the steam. Under such conditions the reading on the pressure gauge is not a true measure of the steam pressure.

REMOVAL OF STEAM BY CONDENSATION

It is apparent that where air is trapped in a retort the air will be at a lower temperature than the incoming steam. This causes undue steam condensation and the "coming–up" time is prolonged thereby.

TEMPERATURE PRESSURE RELATIONSHIP

Saturated steam at given pressures yields known temperatures. Thus at sea level the equivalent temperatures and pressures are as shown in table 4.

TABLE 4.—*Temperature pressure relationship*

Pressure (pounds)	Temperature (° F.)	Temperature (° C.)
0	212.0	100.0
1	215.6	102.3
2	218.6	103.6
3	221.7	105.4
4	224.4	106.9
5	227.2	108.7
6	229.7	109.8
7	232.3	111.3
8	234.8	112.6
9	237.1	114.1
10	239.5	115.3
11	241.7	116.5
12	243.8	117.6
13	245.8	118.9
14	247.8	119.9
15	249.7	120.9
16	251.6	122.0
17	253.6	123.1
18	255.5	124.3
19	257.0	125.0
20	258.8	126.0

Many ordinary vented retorts are pressure controlled, that is, the temperature of the retort is regulated by varying the pressure. Thus to process at 240° F. the controller is set to maintain a pressure of 10.3 pounds. However, should the retort be insufficiently vented so that a mixture of air and steam instead of steam alone be present, the controller would continue to maintain a pressure of 10.3 pounds but the temperature would be considerably less than the 240° F. desired. For this reason, a pressure–controlled retort must be properly vented so as to contain steam only.

THERMAL DEATH TIME

Thermal death point is defined by bacteriologists as the lowest temperature at which a bacterial culture will be killed in 10 minutes, and is not a constant for all bacteria. Micro–organisms differ widely in their resistance to heat, in fact, they have the widest range of temperature resistance of all forms of life. Certain types of bacteria grow and thrive in cold–storage plants, others in hot springs. Most bacteria, yeasts and molds have an active growing range at temperature about 80° F. which may be considered as their optimum temperature, growth usually ceasing at 100° F.

The growth range of certain organisms, known as thermophiles, is at considerably higher temperatures, or from 100 to 120° F. Yeasts, molds and growing cells of bacteria are killed at temperatures of from 170 to 190° F. Spores are more resistant and are destroyed only by prolonged heating at 212° F., although they usually are destroyed readily by heating at 250° F. for a short time. It is the heat-resistant bacteria which cause trouble in canning, especially the thermophiles. The spores of this type of "heat loving" bacteria have withstood boiling water for 20 hours and a temperature of 239° F. for 10 minutes.

In a study of 14 types of thermophilic organisms, 3½ hours were required to destroy the spores of the least resistant and 20 hours at 212° F. for destruction of the most resistant strain. Thermophiles are important as a cause of such types of deterioration as "off" odors or flavors, or spoilage as in "flat sours." Since the thermophilic bacteria always develop at relatively high temperatures, that is, from 100 to 120° F., canned goods should always be stored in a cool place to reduce the possibility of loss through the activity of these organisms. The thermophilic types do not produce poisonous toxins. While *Clostridium botulinum* is heat resistant when in the spore stage, it is not a thermophile.

From the data available, it appears desirable to heat the material at the point of slowest heating of each container to 250° F. for at least 3 to 8 minutes or to process it for equivalent times at other temperatures. By equivalent process it is meant that time and temperature are the only variables and other factors such as degree of contamination, rate of heat penetration, or size of container remain unchanged.

VACUUM

The degree of vacuum in a container has a direct bearing on sterilization only when the rate of heat penetration in the can is dependent upon the vacuum. The rate of heat penetration is affected when heating is by conduction and the can contents are composed of small pieces, with open spaces which are not filled with liquids, such as dry–pack shrimp. Products are considered to be vacuum–packed when a can containing solid pieces has only a small amount of added liquid and the air surrounding the pieces is evacuated mechanically.

When vacuum-packed products are processed, the slight amount of liquid in the can vaporizes, that is, forms steam and fills all the spaces between pieces. However, if the can was not evacuated and the spaces between pieces are filled with air, the partial pressure of the air will retard the development of steam and consequently the rate of heating of the pieces. Thus, if a process time and temperature were worked out on the basis of a high (28- to 30-inch) vacuum in a can and actually the vacuum were much less, the process might be insufficient for sterilization through the retardation of heat penetration by air in the can.

COOLING

During the first part of the cooling operation, the contents of the can are still at temperatures sufficiently high to have sterilization value. Heating continues for some time after removing the can from the retort, the time depending on the temperature maintained in the retort during the processing period. The higher the retort temperature, the greater will be the percentage of total sterilizing heat received by the can during the cooling operation.

In the selection of a process, the sterilization received during the cooling and also the sterilization received during the "coming-up" time, should not be considered as part of the process time. The heating part of the process, from the time the retort reaches processing temperature until the steam is turned off, should be sufficiently long to insure sterilization. The sterilization received during the heating-up and cooling periods is then regarded as an added safety factor.

The containers should be cooled as rapidly as possible for uniformity of processing and to maintain the quality of the product. When cooling is too slow, the following factors adversely affecting quality may occur: (1) Destruction of desirable color and flavor; (2) adverse effect on the texture of the product; (3) favorable temperature for thermophilic growth; (4) increased chemical activity causing corrosion; and (5) change in the drained weight by the extraction of soluble proteins.

ADDED ACIDS

It has been found that acidity, especially that due to such organic acids as citric and acetic, has a marked effect on the death temperature of the spores of *Clostridium botulinum* and other heat-resistant micro-organisms. The presence of these acids has been advanced as the reason why canned fruits are easily sterilized and are so rarely the cause of botulinus food poisoning.

It is now the custom to change the acidity of some marine products during the canning operation. Crustaceans such as shrimp, crab and lobster have a neutral or alkaline reaction which is changed by the addition of tartaric, acetic or citric acids. However, acids are added to these crustaceans to prevent the formation of discoloring sulfides and not primarily as an aid in sterilization. The addition of organic acids is believed to aid in preventing the formation of struvite crystals (magnesium-ammonium phosphate). These are glass-like crystals sometimes found in canned seafoods and meat products and their presence leads to the belief that the product contains broken glass. While the crystals are perfectly harmless and readily soluble, the product is unmarketable when they occur, due to this belief.

ALTITUDE

The temperature of steam retorts operated at pressures higher than atmospheric pressure is not affected by altitude. The thermometer will give the same readings as at sea level. The barometric pressure decreases as the altitude increases, changing the pressure-temperature relationship in processing. Canners who rely on the pressure gauge alone must increase the pressure in processing by 1 pound for each 2,000-foot increase in altitude in order that the pressure-temperature relationship may be maintained and the possibility of underprocessing avoided. Overfilled cans of fishery products or containers with insufficient vacuum may become "swells" at higher altitudes due to the decrease in external pressure.

OIL CONTENT

Extensive studies in the canning of meat indicate that high fat content of the product increases the difficulty of securing an effective process, the fat forming a protective sheath for spoilage organisms. It has been demonstrated clearly that the heat resistance of micro-organisms is increased under such conditions. Oil in canned fishery products may likewise act as a protective coating for spoilage organisms.

Products of high oil content such as chinook salmon or those packed in oil such as Maine sardines and tuna should, as a safety measure, be given a heavier process than might otherwise seem necessary when judged from the rate of heating of the product. Many packers believe that oil-pack sardines are easily sterilized but this assumption is not correct; the process should be at higher steam pressures and for longer periods of time than many packers have believed necessary.

STRATIFICATION

In some products, such as fish chowder, clam chowder and especially oysters, the contents of the can may be stratified into two or more layers of different consistency with the heavier layer or mass at the bottom of the can. The point of greatest density, not necessarily the center of the can, should be used in heat-penetration studies in order to determine the process in products where a separation of contents takes place. Stratification may make a sterilization process insufficient, where this factor has not been considered.

VACUUM IN CANNED FISHERY PRODUCTS

The mechanical and chemical reasons for desiring a vacuum in canned food products are: (1) To keep the ends of the cans collapsed; (2) to prevent unnecessary strains on the containers during processing; and (3) to reduce chemical activity.

COLLAPSED ENDS

In order to keep the ends of the cans collapsed under the different temperatures encountered during shipping and storage, cans must have a vacuum. Fishery products which are usually canned in cool localities and at sea level must have a high degree of vacuum to withstand storage at higher temperatures and altitudes. For example, in experiments with 1-pound tall cans of salmon, it was found that cans with $\frac{1}{16}$-inch headspace having 8 inches of vacuum at 52° F., the vacuum was reduced to 0 on increasing the temperature to 80° F.

While a can with collapsed ends is not always free from active spoilage, as in "flat souring" for example, collapsed ends are generally considered a good index of the condition of the contents. Food laws concerning the sale or distribution of containers with improperly collapsed ends, such as "swells" and "springers" are constantly becoming more stringent.

CAN STRAINS

Cans are subjected to internal strains during processing. Strain is at a maximum when the center of the container attains the highest temperature during the period the container is in the retort. Internal strains are considerably reduced if the container has a high vacuum and sufficient headspace before processing. In the early days of the canning industry before the importance of obtaining a sufficient vacuum and a proper fill was determined, considerable loss was caused through cans developing leaky seams when subjected to excessive internal strains. Another retort strain occurs on the "blowing-down" of the retort pressure as in non-pressure cooling, and has the same effect as if a pressure equal to that of the retort pressure were added to the internal pressure of the can at "steam off." Cooling under air pressure in the retort is necessary to protect large-diameter cans against strain.

REDUCTION OF CHEMICAL ACTIVITY

Corrosion of the steel base within the tin plate is accelerated by the action of oxygen in air left in the headspace. Excessive headspace or "slack fill" increases the rate of corrosion as the oxygen content is consequently increased.

The top surface area of oval or flat cans is proportionately greater than in other types of containers and the possible amount of headspace is larger. "Vacuumizing" is therefore more difficult with this type of container. If sufficient air is present in the headspace, it is possible that the inside of the containers in some packs of fishery products in flat or oval cans will become almost completely detinned and the containers made "swells" even though no micro-organisms are present.

For example, most of the cans in a parcel of salmon packed in 1-pound oval cans developed into "swells" during storage. When samples from this lot were opened, the inside was found to be almost completely detinned in each instance and the flesh was bleached in color, though normal in odor. No living organisms were isolated from any of the swelled cans. The average amount of headspace was $\frac{7}{16}$ inch and hydrogen gas was found to be present. It is believed that the detinning was caused by the reaction between relatively large amounts of oxygen in the headspace and the metal of the container, resulting in the formation of considerable quantities of hydrogen and the consequent swelling of the containers. A short heat-exhaust was used to secure a vacuum in preparing this pack. A high vacuum would have reduced chemical activity.

The speed of reaction increases rapidly with a rise in temperature in most chemical reactions. It has been calculated that the speed of reaction is doubled with each increase of 18° F. In the instance just mentioned, the salmon was held in a storeroom at a temperature between 70 and 80° F. If it had been held at 50 to 60° F., the speed of reaction would have been halved and the amount of detinning minimized. For this reason canned goods should be stored in a cool place, especially if the vacuum is low.

Non-processed products in hermetically-sealed containers, such as salt cod or smoked salmon, may develop a rancid flavor and "rusty" appearance if oxygen is present in the headspace of the container or interstices of the product. This may be reduced to a minimum by sealing in vacuum.

FACTORS INFLUENCING VACUUM

The vacuum obtained in any container is influenced by the following factors:

TEMPERATURE AND ALTITUDE

Altitude has an effect on vacuum similar to the effect of an increase in temperature. Since fishery products are usually canned at sea level with much of the production shipped to high-altitude areas in the interior, this reduction of vacuum is at times sufficient to cause cans having several inches of vacuum at sea level to become "springers" or "swells" on arrival at the destination even though there has been no change in temperature. Loss of vacuum amounts to approximately 1 inch per each 1,000 feet change in elevation. (See Fig. 2.)

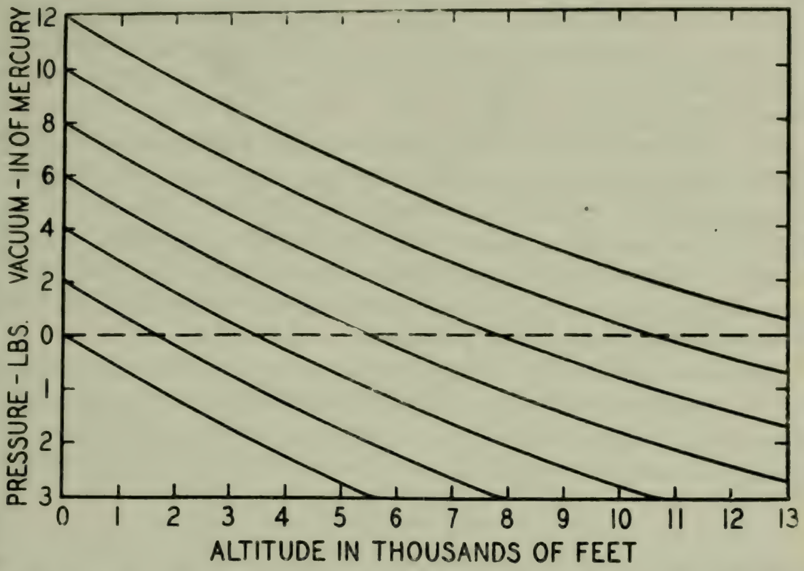

FIGURE 2.—Temperature-altitude relationship in vacuum. (After Northwest Branch, National Canners Association, and *Pacific Fisherman.*)

If canned fishery products (or any other canned foods) are shipped to localities which are both higher in altitude and warmer in temperature, the reduction in vacuum may be sufficiently severe to cause the ends of the cans to bulge. Therefore, the effects of temperature and altitude are additive.

METHOD OF EXHAUST

Air may be exhausted from a container (a) by heat, or (b) mechanically.

Heat exhaust.—The oldest type of exhaust, still used to some extent in packing such products as clam chowder, is to fill cans with a hot precooked product and to seal these containers before cooling. Vacuums of 12 or 13 inches may be obtained if there is no delay between precooking and sealing, but if containers are not filled and sealed promptly the vacuum may be insufficient. This is most likely to occur where the product is prepared in batches or in small plants where filling is by hand.

Until recently, in packing canned fishery products, vacuum was obtained by heat exhaust utilizing an apparatus known as an "exhaust box." Several slightly different types are manufactured but in principle all are steam chests at temperatures of 200 to 212° F. Steam exhaust-boxes are still in use to some extent but are being replaced by vacuum can-sealing machines which exhaust the cans mechanically. The size of exhaust boxes and the speed at which they are operated varies in different canneries and in the packing of different products, giving a heat exhaust varying from 3 minutes in the canning of alewife (river herring) roe, to 20 minutes in the canning of mackerel.

The vacuum obtained by steam exhausting depends on the sealing temperature of the contents of the can and the amount of headspace at the time of closure, the higher the temperature and the less the headspace the greater the resulting vacuum. Usually a long exhaust at moderate temperatures (200° to 210° F.) is better than a short exhaust at higher temperature as in the case of exhaust by steam under pressure.

Mechanical exhaust.—Vacuum may be created mechanically by (1) a suction pump, (2) a steam ejector and (3) a steam blast at closure. A suction pump is probably the most widely used mechanical means of obtaining a vacuum in commercial canning.

HEADSPACE OR "FILL" OF CAN

Expansion of contents.—Solids and liquids expand when heated, displacing a certain amount of air, later contracting on cooling to the original volume.

Vapor pressure.—In an open can, the vapor pressure of the water present, plus the pressure of the gases in the headspace are at equilibrium with the atmospheric pressure. During exhausting, if the contents of the can are heated there is an immediate increase in vapor pressure from the water. According to Dalton's Law the combined pressures of vapor and gas cannot be more than atmospheric pressure; therefore the pressure due to gas (air) present must decrease with the resultant expulsion of headspace gases.

If the can be sealed and cooled, the vapor pressure falls to the definite pressure for that temperature. There will then be less pressure in the can and, since pressure and vacuum are inversely related, the lowered pressure will result in the formation of a vacuum. The partial vacuum, due to this lowering of the vapor pressure, may be calculated by subtracting the vapor pressure at the time at which the vacuum is determined from that of the closing temperature. For example, the vapor pressure of water at 132° F. is equivalent to a column of mercury 4.75 inches in height, while at 72° F. it is 0.75 inch or a difference of 4 inches. Therefore, the partial vacuum due to decrease of vapor pressure after exhaust and sealing is, in this instance, 4 inches.

The amount of headspace affects the degree of vacuum present in a container. For example, 2 cans are packed with the same vacuum but each has a different headspace: Can "A" 1/4 inch, and Can "B" 1/8 inch. If shipped to a warmer climate where the can contents expand sufficiently to reduce the headspace of "B" by one-half, then the headspace in "A" would be decreased only by one-fourth. Since the headspace gases are confined in a smaller space they exert increased pressure. The increase due to expansion of contents alone (excluding gas expansion) in "B" is 100 percent, but in "A" is only 33 percent. Can "B" has twice its former "pressure" while "A" has only 1 1/3 times its original "pressure" and may, therefore, still have sufficient vacuum to retain the can ends in a collapsed state, when Can "B" has lost its vacuum and may become a "springer."

TABLE 5.—*Partial vacuums due to various factors*[1]

Cans sealed at 132° F. and cooled to	Vacuum due to contraction of liquids and solids	Vacuum due to decrease in vapor pressure	Vacuum due to contraction of gases	Total vacuum
F.	*Inches*	*Inches*	*Inches*	*Inches*
122	1.10	1.13	0.43	2.66
112	1.87	2.02	0.85	4.74
102	2.50	2.71	1.28	6.49
92	2.97	3.25	1.70	7.92
82	3.31	3.66	2.13	9.10
72	3.57	3.97	2.55	10.09
62	3.74	4.19	2.98	10.91
52	3.69	4.36	3.41	11.46
42	3.74	4.48	3.83	12.05
32	3.64	4.57	4.26	12.47

[1] The influence of various factors on the total vacuum produced in a 1-pound tall salmon can containing 432 grams of distilled water and having 29.92 cc. headspace when heated to 132° F., sealed, and cooled to various temperatures. Atmospheric pressure equals 29.92 inches of mercury. (Adapted from "The Function of Vacuum in Canned Salmon.")

Expansion of gases.—During exhaust by heat the gases in the headspace expand. Since the headspace in the can decreases during heating, a portion of the expanded gases is forced out by: (1) Expansion of solid and liquid contents, (2) increase in vapor pressure, and (3) expansion of headspace gases themselves, each of which exerts influence upon the partial vacuum in the can on cooling. Some of the headspace gases are forced out in expanding. If the can is then sealed hot and then cooled, the contents will contract with the formation of a partial vacuum in the headspace.

DELAY BETWEEN EXHAUSTING AND SEAMING

In order to obtain a suitable vacuum when using a heat exhaust, the cans should be raised to a high temperature in the exhaust box and sealed immediately. If the contents of the can are cooled to any degree before the container is hermetically sealed, there is an appreciable loss of possible vacuum, as may be seen by consulting the preceding table. Cans sent through a heat exhaust without covers lose a certain amount of possible vacuum before seaming. The practice of exhausting cans with lightly clinched covers has been followed as a sanitation measure but is also useful as a means of heat conservation.

LOOSE SEAMS

Strange as it may first appear, loose seams can be responsible for a very high vacuum. In processing, all gases present in such cans at the time of sealing will be expelled through the loose seam. At the beginning of cooling, if particles of the product should clog the seams so that air may not enter the container, a very high vacuum will result. Such "self-sealing" cans are known as "hot leaks" or retort exhausts. In extreme cases the vacuum created is sufficiently high to collapse the container under normal atmospheric pressure.

However, the great majority of loosely-seamed cans do not seal themselves during the process. Such cans are characterized by lack of vacuum and usually absence of about half of the can contents which has escaped during processing and are known as "blown" cans. Paper gaskets, which are somewhat porous when used for non-processed or "dry" products, may "breathe" and contribute to loss of vacuum.

FRESHNESS OF PRODUCT

Stale products where some decomposition has taken place generally have a tissue filled with minute gas pockets called "honeycomb." Though usually small in size, these pockets may be quite large in salmon and tuna. During retorting (processing), these gases which may not have been displaced or driven out during the exhaust expand and are forced into the headspace of the can which reduces the vacuum. If a strong odor is encountered and there are other indications of lack of freshness in well seamed low-vacuum cans, the contents should be examined for honeycomb. Honeycomb is seldom encountered today in canned fishery products due to improvements in canning technique and closer control of raw materials.

EXPANSION RINGS AND WEIGHT OF TIN PLATE

The tops and bottoms of cans are usually circled with large concentric indentations or ridges called expansion rings, for the purpose of stiffening the can ends. Some flexibility in tin cans is desirable since expansion during processing serves to reduce internal strains. However, flexibility from a vacuum standpoint is undesirable because any collapsing or "drawing-in," "pushing" of the can through dents, panels or similar causes, effectively reduces the vacuum.

The weight of tin plate and can size are also factors to be considered. A No. 10 can is manufactured from heavier plate than that used for cans of smaller sizes, yet even so this can "panels" badly if sealed with a moderate vacuum or at too hot a filling temperature; cans of a smaller surface area do not panel even though made of lighter plate. Heavier tin plate will counteract lack of vacuum in smaller-sized containers. A few salmon packers formerly did not use any method of exhaust but instead used extra-heavy ringed ends known locally as "boiler plate ends" rigid enough to resist any internal can pressure caused by a change in temperature or altitude. With the introduction of mechanical vacuum seamers this practice was discarded and is rarely, if ever, followed today.

SOLUBILITY OF HEADSPACE GASES AND ABSORPTION OF OXYGEN

Carbon dioxide is present in nearly all classes of canned foods. Carbon dioxide becomes less soluble with a rise in temperature and may then be forced into the headspace of the can with a corresponding reduction in vacuum. Nitrogen acts in much the same manner.

If an analysis is made of the gases in food packed in plain tin cans after they have been in storage for a few weeks, an almost complete absence of oxygen will be indicated. The gas present will be largely nitrogen, although if much corrosion has occurred, hydrogen may be present. The oxygen combines with the tin plate, and to some extent with the product after it is sealed in the can, and is no longer present in a free state. The vacuum is increased since the internal gaseous pressure is decreased by an amount corresponding to the absorption of oxygen. The absorption of one-fifth of the total amount of gases, that being the proportion of oxygen in air, results in a fair degree of vacuum or about 6 inches.

In salmon the absorption of oxygen for example seems to be due to the presence of unsaturated oils, which take the oxygen into combination, with the resultant creation of a vacuum.

TEMPERATURE AT WHICH VACUUM IS TAKEN

If a vacuum is taken shortly after the samples are removed from incubation at 27 to 55° C. in the examination of canned foods, the results obtained will indicate a very low vacuum. The examination will indicate quite a high vacuum if the samples of the same goods are examined just after they have been removed from storage at low temperature or after transportation during cold winter weather. Therefore it is essential that all vacuum determinations be made at some uniform temperature, which in usual practice is about 68 to 70° F. This is illustrated in fig. 3, showing the temperature-vacuum relationship in the canning of salmon.

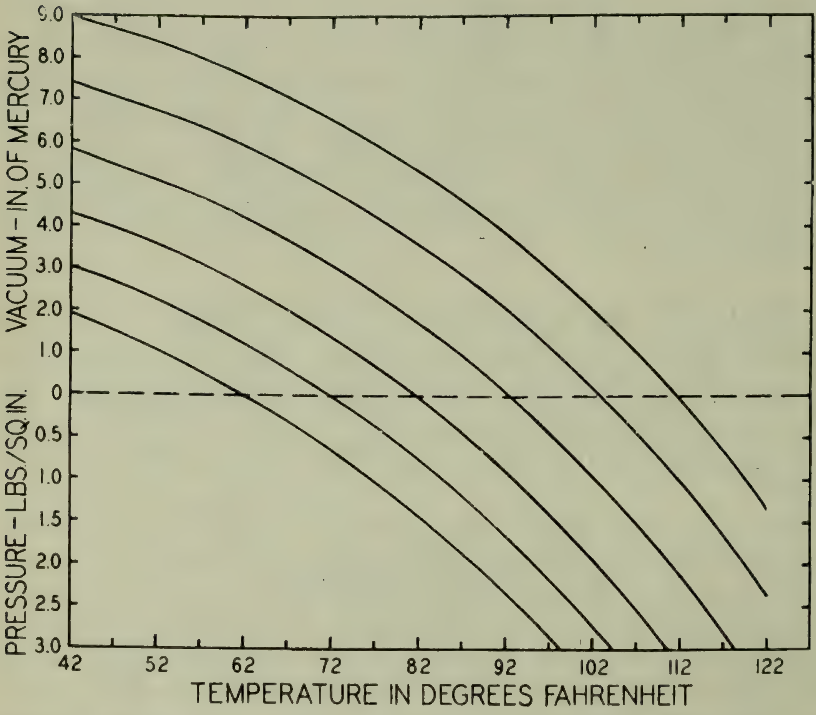

FIGURE 3.—Temperature-vacuum relationship in the canning of salmon. (After Northwest Branch, National Canners Association and *Pacific Fisherman.*)

FACTORS TO BE CONSIDERED IN ESTABLISHING A CANNERY

In considering the establishment of a cannery a series of factors vital to commercial success must be given careful study. The study should be made preferably by specialists such as food technologists, food-plant engineers and experienced canners. Some of these factors are: (1) Supply of raw material to be used in canning; (2) suitable cannery site; (3) length of canning season; (4) transportation; (5) labor supply; (6) water supply; (7) management; (8) marketing and sales, and (9) capital.

SUPPLY OF RAW MATERIAL

The species of fish, shellfish, or crustaceans available must be suitable for canning. Some species do not make as appetizing or marketable a product when canned as in the fresh condition. Definite assurance should be had that the supply of raw material is not subject to depletion or exhaustion. In certain areas, species suitable for canning may bring a better price in the fresh or frozen market than it is economical for the canner to pay. The first requisite is a sufficient supply of suitable raw material. A fishing area may offer a considerable number of species, but individual species may be present only in small numbers or at infrequent intervals. Variations in the annual supply of the most plentiful species may increase the overhead costs to the extent that canning may become unprofitable. Consideration should be given to the supply of supplementary commodities which could be canned to cover overhead costs, otherwise the principal canning operations may become too expensive for competition with other areas.

SUITABLE CANNERY SITE

A cannery should not be located in a particular site merely because it may be obtained cheaply. The site should be as near as possible to the fishing grounds or area from which the raw material is obtained or commonly landed. A waterfront location is almost essential and there should be sufficient depth of water so that it will be possible to land fishing boats, cannery tenders or lighters alongside the dock at any stage of the tide.

If the product is to be of first-class quality, the raw material must be landed promptly. Delay in landing the catch means that the cost of operation is higher than necessary. A good sweep of the tide is also desirable so that oil or any other waste material will be carried far out and will not be left to pile up and decay on the beach or shore around the plant.

There should be enough level ground at the site so that the necessary buildings may be located conveniently adjacent to the dock in a single unit, with sufficient space for the various operations and with adequate allowance for possible expansion. It should not be necessary to set all buildings on docks over the water, because such plants are more expensive to construct, are subject to moisture losses in storage, and there is greater danger of loss by storms.

Most fish canneries are in isolated locations, but some are operated near centers of population. In the latter instance a waterfront location near the vicinity of a beach resort or residential area is not desirable even though it may not be forbidden by zoning regulations. No matter how careful the management may be to keep the establishment clean and to eliminate any possible nuisances, the presence of the plant will be resented, the operations will encounter hostility and the product will receive unfavorable advertising. The ideal location answering all requirements will probably not be found but selection should be made of the site which most closely approaches the ideal.

LENGTH OF CANNING SEASON

The overhead cost per case of product is high when the canning season is short. The salmon canning season in Alaska is brief, and few canneries pack any other products. The salmon-canning industry is able to compete with producers of other canned fishery products only because it has developed mass production machinery and methods enabling it to turn out a greater daily production, using much less labor than is necessary in other canning industries.

It is possible for fish canneries in California to operate over a much longer annual period than in many other localities due to the availability of several suitable species, such as tuna, sardines and California mackerel, caught in large quantities in or near the area at different seasons of the year. Some canneries pack specialty products when the raw material on which they principally depend is not available. Norwegian sardine canneries may pack fish balls, fish pastes, anchovies or similar products, in the "off" season.

TRANSPORTATION

Transportation is even more important to the canner of fishery products than to other food packers, since unusual transportation problems are encountered, not met with elsewhere. Storms and bad weather do not affect transportation on land to the same extent as they do at sea. In establishing a cannery it should be determined whether regular transportation is available at reasonable rates. Although all other operating factors may be favorable, if freight rates are high, operation may be made impossible or the canner may be forced to provide and operate his own means of transportation between the cannery and the primary market. A small establishment operating a single plant may find ship operation as great an expense as high freight costs or charter rates. In many instances the canner must not only transport his pack to the primary market but must bring in all supplies, packing containers and even crew from a distant locality.

Sufficient transportation also must be arranged to carry the raw material from the fishing grounds in the shortest possible time and land it at the cannery in good condition. Some canners find it most satisfactory to operate their own transporters of raw material while others charter these craft. Local conditions determine which system is preferable so the canner should endeavor to secure comparative data on costs before buying his own tugs, lighters or scows, "buy boats" and other floating equipment used.

LABOR SUPPLY

Successful canning requires the services of a sufficient supply of experienced labor. It is a mistake to set up a cannery in an effort to give employment to inexperienced labor. Where the workers are unskilled, workmanship in packing is poor, there are losses in the pack due to ignorance and lack of skill, speed of operation is less and therefore operating costs are increased greatly. Unskilled workers may be trained but sufficient skilled labor must be available to carry on during the training period, and the required skill is not acquired in a single canning season.

The number of workers required depends on the size of the plant, the product packed and especially the amount of hand work in cleaning, and filling. Shrimp canning probably requires the greatest amount of hand labor per case, while in salmon packing it is reduced to the minimum.

The erratic nature of the employment adds to the difficulty of securing skilled workers. A fixed work day period is impracticable since the raw material is extremely perishable, is brought in more or less irregularly, and must be processed as soon as possible. A longer canning season not only reduces overhead but is often an inducement to trained workers.

While it is desirable to provide as much employment as possible, especially where good–quality workmanship in packing is important, overhead must be kept at the lowest level commensurate with quality. This usually requires the mechanization of operations to the fullest extent possible. In some cases it may be more desirable and profitable to make use of a small number of highly paid and dependable machine operators, thus reducing to a minimum the number of less dependable hand workers.

WATER SUPPLY

One of the most important factors in establishing a cannery is the availability of an adequate supply of good fresh water. All water used around a cannery should be potable, that is, of good drinking quality; free from any possibility of sewage contamination and low in mineral salts, especially sulphates and iron salts (Cruess, 1938). "Hard" waters containing appreciable quantities of calcium and magnesium salts also should be avoided, not only because of any possible effect on the product but because of damage to boiler tubes. Such water may be made fit for use by the installation of a water softener.

It is desirable that supplies of fresh water not only should be sufficient for canning purposes, for fish boat and cannery crews, and for use in the boilers, but also should be adequate for all cleaning and washing operations. Salt water pumped from the vicinity of the plant should not be used since it is often heavily contaminated with spoilage organisms and is therefore dangerous. Any water supply should be thoroughly sampled and subjected to chemical and bacteriological analyses before use, following the procedure described by the American Public Health Association.

Wells are sometimes driven to eke out an otherwise inadequate water suppy. Shallow wells are apt to be contaminated, but as a rule water from deep wells and springs contains few micro–organisms. According to Marshall (1921) lake water, especially at some distance from shore, is generally much purer than river water.

The pressure and volume of water is very important in washing or cleaning the raw material, and in general cleaning or "washing–up" operations around the plant. If the water is delivered under low pressure or if the pipes are too small, this work will be done poorly and require more time.

MANAGEMENT

In the final analysis, successful operation of a cannery and the production of a high–quality product depend on the management. The packing of fishery products is much more speculative, and requires an even greater degree of skill in organization and administration than in other branches of the food–canning industry.

The superintendent of a successful seafood cannery should be experienced in the canning of fishery products, should possess a good fund of technical information in this field, and should be a good organizer, capable of handling the fishermen and other workers to best advantage, and should have the ability to merit their confidence and respect. It is also essential that he should be assisted by foremen and machinists who are capable, experienced in the canning of fishery products and who will not permit carelessness in packing.

In the establishment of new canneries, especially those for which funds have been obtained through public subscription or which are otherwise "community organizations", it is a mistake to engage as superintendent or manager the man most active in the promotional work. A man may be a good promoter without being a good executive.

MARKETING AND SALES

Some fish–processing establishments fail because proper attention has not been given to the marketing and sale of the product. Few products "sell themselves", but the cost of a top–heavy sales organization can nullify efficient production methods. Establishments introducing a new product must carry on an intensive educational campaign and be prepared to wait several years before being able to go into production on a large scale. New packers of a standard product must be ready to compete with established packers by offering inducements in superior quality or favorable price.

The first pack of canned salmon in 1864 totalled only 2,000 cases but the packers had a great deal of difficulty in selling this quantity, disposing of some in door to door sales before wholesale buyers could be found for the remainder. The tuna–canning industry in the United States dates from 1903 and the pack of that year was 250 cases (Cobb, 1919). After 9 years of effort the total pack of canned tuna was only 78,900 cases (Anonymous, 1938), yet today it amounts to 1,970,000 cases, with a value to the packers of more than $10,000,000 (Fiedler, 1938).

Only large packers of canned fishery products can afford to maintain their own marketing and sales organizations and even they have found the cost too great in some instances. The average packer finds it more effective to use the services of primary marketing agencies which may act as distributors of a large variety of canned foods. These agents are usually termed brokers and their average commission is 5 percent of the price received. As a rule this commission is divided equally between the primary marketing agency and the distributing brokers in the various markets.

The broker not only acts as an agent in selling the pack but undertakes all the details of marketing and distribution, and also handles collections. He also serves as a medium for exchange of information between packers and the distributing trade. Domestic sales are usually on an f.o.b. basis, the buyer paying shipping costs. It is also customary for packers to allow a cash discount of 1½ percent on sales.

CAPITAL

Insufficient capital has contributed to the failure of a number of fish–canning enterprises. This is especially true in attempts to introduce new products. Before commencing operations any new canning enterprise should make sure that sufficient capital is available for operating expenses. Even though insufficient capital is not a cause of complete failure it invariably increases cost of operations, thus contributing to the loss of possible profits. The packer must pay a higher price for canning supplies and is forced to dispose of his pack at the earliest possible moment, either because of demands for repayment of loans or because he is not in a position to resist the pressure of wholesale buyers for lower prices.

The amount of capital required will vary with the locality, the type of product packed, conditions under which it is marketed, and the skill and business ability of the packer. Some men will always require more funds than others under the same conditions. Canners operating on a small scale must have a proportionately larger capital per unit of production than large–scale packers. A hard–and–fast rule as to the amount of capital required cannot therefore be laid down but the best information available indicates that the capital of a fishery–products cannery should be $2.50 per case packed.

FACTORS IN CANNERY CONSTRUCTION

Certain important factors of cannery construction should be given careful consideration before the designing and building of a fishery products cannery is undertaken. These factors are as follows:

SPACE NEEDED

One of the principal faults in cannery construction is failure to allow sufficient space for efficient operation. It is sometimes considered necessary only to have the essential machinery crowded into the smallest possible space. Sometimes a cannery building is constructed without considering the variety of pack and extent of operations. A building should not be erected and *then* adapted for cannery purposes. Efficient operation requires that the space needed for proper placing of the equipment be considered and the building then planned around the required equipment. Some idea of the amount of space needed in packing the more important products may be gained by consulting flow-sheets or lay out plans included under the sections describing the methods of packing individual species.

If the canning plant is to pack several different products at different seasons, such as fish flakes, followed by fish cakes, pet food and various specialty products, the space should be large enough to accommodate extra equipment which cannot be dismantled readily and removed when not in operation. A plant of this type packing about 400 cases per day and operating one "line" of machinery should have at least 2,400 square feet of floor space. This requirement does not include space for storing empty cans or for a boiler room or machine shop but provides only for actual packing equipment and facilities. The length of the cannery should be approximately twice the width because an efficient lay–out of equipment is harder to plan in a square or almost square space.

DIVISION OF SPACE

Not only should the cannery building be sufficiently large to accommodate adequately all packing operations but also the division of space should be proportionate to the requirements of the different steps in canning. For instance, the retorts or cookers may be poorly placed and cramped, while there is more space than necessary around the closing machines. The division of space will depend on the amount of butchering or cleaning and the extent of precooking or preparation required. Hand filling requires much more space than machine filling; less space is needed by the vacuum sealer than the exhaust box, and when the pack is cooled in the retorts, space previously allotted to this stage of processing can be devoted to other uses.

Frequently entirely too small an area is devoted to cleaning, or dressing and washing. Then the raw material accumulates excessively on the cleaning tables and the entire cannery is forced to reduce the rate of operation, thereby increasing the cost of packing per case. There is likelihood of poor cleaning under such conditions, which lowers the quality of the canned product. The amount of space needed for cleaning depends on whether storage bins for raw material are required, the species of fish or shellfish packed and whether or not any degree of machine dressing is involved. Storage bins and hand dressing require more space than would otherwise be necessary.

It is frequently desirable to wall off the cleaning area from the rest of the cannery floor. Sometimes this is done for reasons of sanitation, as in the packing of shrimp and oysters, while in other instances, it is done so visitors will not receive and spread misleading ideas as to the quality of the product.

If the cleaning department is in a building separate from the main cannery the two should be placed as close together as possible. If the two departments are not adjacent, the length of time spent in packing the raw material and the likelihood of contamination and spoilage are increased, the possibility of delays or breakdowns is greater and there is more opportunity for bruising the raw material in carrying it to the precooking or preparation stage. Long conveyors or elevators or those which drop or throw the raw material when unloading should also be avoided.

LOCATION OF CANNERY BUILDINGS

It is usually advisable to place the boiler room at least 50 feet from the main building to reduce the fire hazard. If the cannery includes a blacksmith shop this should also be detached for the same reason. Buildings for the storage of gasoline, oil and all other inflammable materials such as lacquer or benzene should be constructed on the end of a long wharf at the greatest possible distance from the cannery proper. If the type of gear used requires tanks for tarring nets these should also be placed at a distance from the cannery and especially remote from the vicinity of the gasoline and oil tanks.

Racks for drying and hanging nets should be adjacent to the fish–boat landing. If the racks are on land they should have a wooden floor raised several inches above the ground level. Where net racks are too small the nets are not well tended and more time is required than is necessary. Conn reported that direct rays of sunlight have a weakening effect on linen or cotton net fiber.[1] If a roof were placed over the net racks, the life of the nets would be increased but so far as known this is not done at present. Marine ways should be conveniently placed with respect to the machine shop, blacksmith shop, stock room and boiler room.

STORAGE BINS

Bins are coming into wider use for the temporary storage of raw material in the canning of seafood products. Such bins should be shallow, generally sloping to the unloading point. Fish piled in the bottom of deep bins will be over–heated and the flesh softened by excessive pressure. Bins with sloping floors are preferred since flat bottomed bins are not as well adapted to sluicing, do not drain well and retain some of the fish to contaminate other lots later.

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[1] Conn. W. T. 1933. More life from fish nets. Spec. Memo. 1651–H ; U. S. Bur. Fish., 14 pp [Processed.]

Partitioned storage bins or boxes should be used to prevent deterioration of raw material. There should be no corners or cracks from which debris cannot be removed readily. All bins (boxes) must be water–tight, well–drained and ventilated.

Plain wooden bins absorb slime and water and thus become a source of contamination. Bins waterproofed with tar or asphalt are likely to introduce "off flavors" to the product. Zinc–lined bins are satisfactory if the lining is renewed at the first signs of corrosion. The ideal material is one of the more expensive non–corroding metals.

CLEANING

Cleaning should be facilitated by eliminating all narrow spaces which easily catch and retain dirt or waste material. If the cannery is built over the water there should be no spaces under the floor, such as the tops of joists, where pieces of waste material could lodge. Corners formed by the junction of wall and floors should be rounded when possible. The walls, partitions and ceilings should be as smooth as possible so that they may be cleaned more readily. All walls should be coated with a washable paint of light color.

Sufficient water and steam outlets should be provided so that floors, walls, ceilings, tables and machinery may be flushed readily without dragging long lengths of hose over and around equipment. Water pipes should be at least 1½ inches in diameter, with the water delivered at a minimum pressure of 50 pounds per square inch. All openings in the main cannery building should be fitted with screens.

TYPE OF CONSTRUCTION

While frame buildings are usually less costly, especially in the more important fish canning areas, concrete and steel or corrugated sheet–metal construction is more durable and desirable because of a lower fire hazard and better sanitation. Many of the specifications for the construction of a meat–canning plant may be applied to the building of a fish cannery.

The fish cannery preferably should be constructed as a one–story building because conveyor belts and other automatic–handling systems are more readily installed and it is easier to maintain an unbroken flow of material. Sagging in floors has been known to throw machinery out of line on the upper floor and to cause trouble in the operation of machinery on the lower floor by disturbing the alignment of shafting and pulleys suspended from the ceiling or joists overhead. Low-hanging shafting should be avoided as it is a cause of accidents.

CEILINGS AND VENTILATION

All ceilings should be high and no ceiling should be placed on overhead joists to form an attic as good ventilation is essential to sanitation and in maintaining a good rate of production. The best ventilation is secured if the roof is of the "saw-tooth" type. Blower fans improve natural ventilation by the creation of a current of air and are suggested for canneries in warm and humid climates.

FLOORS

Concrete makes the best cannery floor. The concrete should be waterproofed but not finished so that it will easily become "slick" or "greasy." The floors should be laid in as large sections as possible since joints do not stand up well under heavy trucking. Also, the floors should be strengthened where machinery is placed and should be braced to reduce vibration especially where the cannery is located over the water. "Patent" waterproof and wear-resisting floors are usually too expensive and are not used extensively at present.

Wooden floors must necessarily be used in a great many instances but all should be waterproofed. All floors should be constructed with a slope of ¼ inch to the foot, but the length of grade in any direction should not be more than 15 feet and no part should be farther than 16 feet from a drain so that waste water will flow off quickly without standing. Drains should not be simply holes in the floor but should be fitted with drain pipes, connecting with the sewer if in a populated area, or to a central drain. This drain should discharge at some distance into a channel with a good tidal flow or into a scow.

DOCKS

Docks should be strong enough to resist a strain several times in excess of the probable maximum load since a number have collapsed, usually when loaded with canned products ready for shipment. Considerable open wharf space should also be provided if fish houses, warehouses or a cannery are built on the dock. If the dock is built of wood, the planking should not be planed smooth or it will be slippery when wet, making trucking difficult and a cause of accidents.

LIGHTING

Good lighting is essential to good sanitation and quality production. Windows should be numerous and large. In addition, skylights should be provided in the roof to obtain the maximum amount of daylight. In some canneries the entire upper half of the walls is of glass. Good lighting improves the morale of employees so that workmanship in packing is better and the output per man greater.

For night operation, care should be taken to provide a sufficient number of lights equipped with reflectors which should be effectively placed to prevent eye–strain. Individual lights of 150 watts are suggested as a minimum.

CONVEYORS

Conveyors not only reduce the amount of labor required in canning but also speed up the output and are used particularly in large canneries which pack for the quantity market. While unnecessary hand lifting and trucking increases the overhead cost, expensive and extensive conveyor systems are not always economical in plants where the production is as small as 300 or 400 cases a day. In these canneries the hand labor required to operate a "line" of canning machinery can usually also do the work performed by conveyors in the larger canneries.

STEAM SUPPLY

A fishery–products cannery usually requires a larger steam supply than a fruit– or vegetable–packing plant. Precooking requires longer periods of time and is usually at temperatures in excess of 212° F. Fish–canning processes are heavier than those used for fruits and vegetables, with the exception of a few of the non–acid vegetables. Unless provision is made for an adequate steam supply the cannery will not be able to process the pack as rapidly as is required during the rush season. In some instances he pack may be insufficiently processed.

The average steam requirements may be calculated as one-half boiler–horsepower per case of production, that is, a cannery with a maximum output of 1,000 cases per day will require 500 boiler–horsepower. This output of steam provides for loss of heat in processing and that needed for cleaning purposes. It is good cannery practice to install 2 boilers each of sufficient size to supply he average daily steam requirements instead of a single large boiler. The cannery may then continue to operate in case of a boiler breakdown, and boilers may be cleaned while the cannery s running.

REFRIGERATION

In some packing districts a few of the larger canneries have found it profitable to operate a freezing and cold-storage plant. If only small quantities of raw material are brought in daily, so that it would be too costly to operate the plant, the fish may be frozen and stored until a sufficient supply has accumulated. On the other hand, if the catch is too large for the capacity of the cannery, the surplus may be frozen, stored, and canned later when the fish are less plentiful. This practice is followed in the albacore fishery off the Oregon Coast. Fish are not injured for canning by freezing. The quality of the canned product is excellent, since the raw material is held in good condition while awaiting canning.

COST OF CONSTRUCTION

The cost of constructing a fishery-products cannery cannot be estimated accurately at a distance since there are numerous variables affecting cost of which the most important are locality, type of construction, fluctuations in labor and material costs, type of products to be packed and the size of the cannery. The only means of obtaining the desired information is to furnish a contractor specifications and obtain a construction bid.

CONTAINERS AND PACKAGES

INTRODUCTION

A variety of different materials has been tested experimentally or has been of some use in the commercial production of canned fishery products at one time or another. In the early days of the canning industry, earthen or stoneware containers of the Scotch marmalade type were used in packing canned fishery products. A Puget Sound salmon packer canned salmon in this type of container to the order of an English buyer. Stoneware jars have been used most widely in marketing such preparations as fish pastes and are still favored to some extent in Europe. The development of "plastics" has turned attention to this material as a possible source for canned food containers but difficulties in manufacturing such containers, troubles encountered in canning and cost considerations have prevented commercial utilization in the canning industry to date.

Only two types of containers are used extensively today in the United States for the commercial canning of fishery products, the glass jar and the so-called "tin" can, although a very small amount of tuna is now packed in aluminum containers in southern California. In the United States objections to the use of aluminum in the seafood canning industry are the high cost of this type of container and manufacturing and packing difficulties. The most extensive researches on the use of aluminum containers have been conducted in Norway where they are most extensively used (Aschehoug *et al,* 1935).

The advantages claimed for aluminum are: (1) Comparatively greater abundance of raw material; (2) no inside blackening of the container; (3) no metallic odor or flavor communicated to the product by the container; (4) the metal only slightly soluble in the product; (5) greater ease of opening the container; and (6) lighter weight of the can. Objections admitted are: (1) Aluminum is attacked by acid products and those of high salt content; (2) since the metal is softer than tin plate, difficulty may be encountered in double–seaming; and (3) lack of resilience requires special treatment in processing if leaks are to be avoided. The use of aluminum as a container for canned tuna is said to be increasing in southern California but it is doubted whether this metal will be used for anything but a few "specialty" packs during the next few years.

GLASS CONTAINERS[2]

Practically every kind of fish product is packed and sold in glass containers to some extent. The advantages of the glass container are: (1) The superior display value of the pack; (2) the neutral quality of the container material which does not react with the acids used in some fish packs; (3) ability to reseal the container, important in the merchandising of such products as fish pastes; (4) re–use value of the containers, particularly the tumbler type used for such products as oysters and shrimp; and (5) the security of sealing combined with comparative ease in opening. Objections to the glass container are: (1) Its weight in comparison with other packages; (2) the possibility of breakage; (3) slower heat penetration; (4) slower packing speeds; (5) color loss through "light striking" as in shrimp; and (6) the slow "come-up" and cooling times in processing.

MANUFACTURE OF GLASS AND GLASS CONTAINERS

Technically, glass is "an inorganic substance in a condition which is continuous with, and analgous to, the liquid state of that substance, but which, as the result of having been cooled from a fused condition, has attained so high a degree of viscosity as to be for all practical purposes rigid." (Morey, 1938.) It will be noted that the quality of transparency is not part of the definition. Moreover, glass is not classified as a solid, such as metal, the molecular structure of which crystallizes in a set pattern upon cooling from the molten state. X–ray photographs show that the molecules in glass assume no regular grouping, as do the molecules in a normal solid. Many of the unusual properties of glass arise from this fact.

The chief components of glass are usually a silica, an alkali, and a body material. The best glass is fused silica, but its melting point is so high that production of pure silica glass is not feasible for commercial articles. The alkali, usually soda, lowers the melting point but the combination of these two elements yields a soluble product. The addition of a third material for body strength, usually lime, produces commercial glass. In actual glass manufacture, there are some 20 forms and varieties of basic materials in compounds in which they are mined; the elements which are not primary glass materials are either utilized to give special properties to the final product or removed in the fusing process. Glass for bottles usually contains about seven–tenths silica, and the rest consists of approximately equal quantities of soda and lime.

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[2] This section prepared by F. P. Gass, Glass Container Association of America.

Small quantities of many other elements are used either as colorizers or de–colorizers, the quantity being determined by an analysis of the batch and the purpose for which the glass is made. Ordinary glass–making processes utilize also a certain percentage of "cullet," or crushed glass, to lower the melting point and consume waste.

The "batch" is mixed by weight, according to formula, and delivered by overhead batch car to the "dog–house," an antechamber of the furnace or "tank." A bridgewall divides the furnace into two connected parts; in the larger part, next to the dog–house, the glass materials are melted at a heat of about 2,500° F., the tank operating continuously. The mass, as it becomes more fluid and under pressure of the solid materials behind it, moves under the bridgewall to the refining end of the furnace.

The molten glass from the refining end is fed to automatic forming machines in the precise quantity required for a bottle, either by being sucked or by being dropped into the forming mold. This mold, one of about a dozen on the perimeter of a revolving table, shapes the neck or "finish" of the bottle; the cool mold hardens the neck, while the rest of the glass hangs in a loose sack. Automatic fingers grasp the half–formed bottle by the neck and deliver it to the blow–mold, also one of a dozen or so identical blow–molds on another revolving table. Here a jet of air blows out the still workable glass to conform to the shape of the mold, and the bottle is passed on down by conveyor to the annealling oven, or lehr. The function of the lehr is to temper the glass by relieving it of its internal strains through a slow controlled–cooking process. Bottles as they come from the lehr are inspected and packed for shipping.

The process of making pressed ware and tumblers, some of which are used in packing fish products, follows a different course after the molten glass leaves the tank. Since the neck opening of a bottle is smaller than its hollow interior, blowing is required for forming, but pressed ware and tumblers may be made without blowing and follow a method more nearly resembling the manufacture of simple iron castings.

TIN CANS

It is estimated that more than 95 percent of the production of fishery products is packed in tin; approximately 964,702,800 cans were used in 1936 by the fish–canning industry (Fiedler, 1938). A few fish canners in the more isolated sections manufacture their own cans but even most of those firms have turned to the use of "re–formed" and "semi–formed" cans which require only that the body be rounded into a cylindrical shape and the end or bottom seamed on. As a rule canneries buy their containers from large, centrally located can factories.

The canner and especially the canning technologist should be acquainted with the methods used in the manufacture of tin plate, but the subject requires a longer description than it is possible to give here. Several recent publications on this subject may be obtained readily (Gonser, 1936; American Can Co., 1939).

COMPOSITION OF TIN PLATE

The composition of tin plate used in making cans is approximately 98.5 percent steel with a coating of tin amounting to about 1.5 precent (Gonser, 1936). Ninety percent or more of the steel used for tin plate is made by the open–hearth method, the remainder by the Bessemer process. The steel used in making tin plate is of the highest grade and should have from 0.05 to 0.1 percent carbon, 0.3 to 9.45 percent manganese, about 0.08 percent phosphorus (less than 0.015 percent for cold rolling steel) and from 0.03 to 0.05 percent sulphur.

CAN MANUFACTURE

The can used during the nineteenth century, known as the "soldered" or "hole–in–cap" can was made with soldered side and end seams. In packing some products, the top with a hole about half its area in size was soldered into place after filling, the container was sent through the exhaust box and a disc covering the hole was then soldered in place. Another method was to solder the lid in place before filling, later soldering on the cap in place. This type of can is still used in packing canned meat and milk products but with a few rare exceptions it has been replaced in fish canning industries by the "sanitary" or open top can. (See Fig. 4.)

Sanitary cans are made automatically on the assembly–line plan by a series of machines, each of which performs a separate function in the process of manufacture. The method is illustrated diagramatically in Figure 5 and described briefly below.

CUTTING BODY BLANKS

Sheets of tin plate as received at the can factory are edge–trimmed, if not perfectly square, and cut by a machine known as the trimmer and slitter, into "blanks" of the proper dimensions for making can bodies of the size to be manufactured. The tin is slit or cut by gang knives or rotary cutters of hardened tool steel. In some plants two single slitters are used, the first cutting strips of a width sufficient to form the circumference of the can while the second cuts these crosswise according to the length of the container.

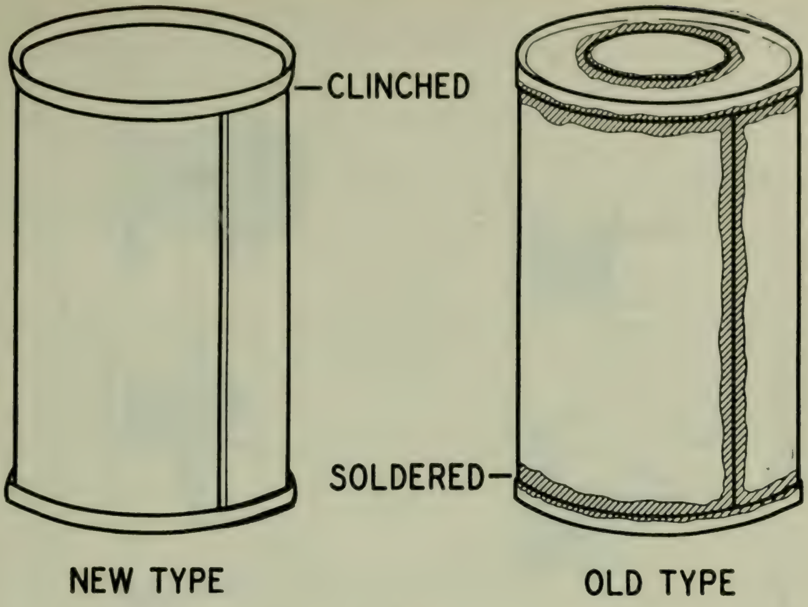

Figure 4.—Old type soldered or hole-in-cap can and modern can. (After International Tin Research and Development Council, Bull. No. 4.)

BODY MAKING

After being cut to size, the body blanks are stacked in the feed magazine of the body making machine. The blanks are fed singly by a vacuum cup from the bottom of the magazine to reciprocating feed bars. These bars carry the blanks to a position where the corners are notched and slit so that smooth joints will be formed at the junction of the two edges of the body, when the side seam is made.

The notched blanks are then carried by the feed bars to an edging station, where the edges are turned lengthwise along the body, and in opposite directions. These turned edges when hooked together will later form the "side lock" or "lap seam."

The flat can body next passes to the body–forming portion of the machine. Here the body blanks are bent into a cylindrical shape by means of "wings," two semi–circular metal forms (termed "roll–form" body–maker), the hooks are caught in place by the use of an expanding mandrel or horn inside the can and the seam is hammered flat by a blow from a hammer attachment. Since the side seam is not yet watertight the can body passes on to a fluxing and soldering attachment. Flux is applied by a narrow wheel, which runs through a bath of alcohol–rosin flux, and brushes

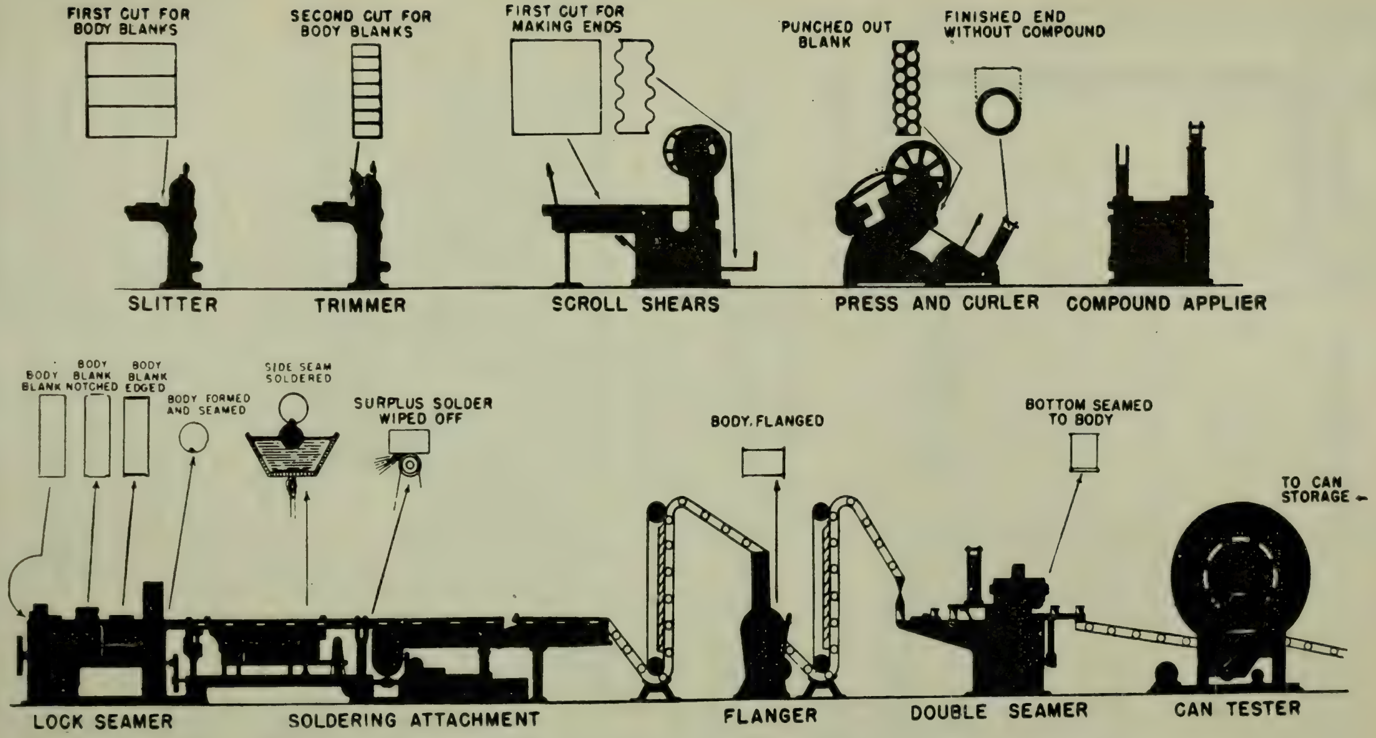

FIGURE 5.—Diagram illustrating steps in the manufacture of cans and can ends. (Courtesy International Tin Research and Development Council, Bull. No. 4.)

lightly against the seam as the can passes overhead. The seam is soldered by a longitudinal roller, which revolves in a bath of molten solder and presses against the seam as it passes above along a "soldering horn." Excess solder is removed from the body of the can by a fabric buffing wheel. As the soldered can body moves along the end of the soldering horn it is cooled by a blast of air from a blower attachment.

FLANGING

The can bodies are carried from the body making machine by a conveyor which brings them into position to be fed by gravity into a flanger. This is a rotary machine equipped with 6 or 8 sets of "flanging heads" or dies. These are convex plungers which are forced into the two ends simultaneously, pressing the edges outward to form perfectly uniform, curved flanges, to which the ends of the can may be later attached by seaming.

DOUBLE SEAMING

Automatic conveyors transfer the flanged can bodies to a machine known as a "double seamer." This attaches the bottoms to the cans and the same type of machine seals on the top after the can is filled. The machine used in can making is, however, operated at a much higher speed; at approximately twice the rate customary in canning. The end sealed on in can making is known as the "factory end." The subject of double seaming is discussed under the operation of canning machinery (p. 69).

CAN TESTING

The finished cans must be inspected for leaks after seaming on the end, so from the double seamer they are carried by conveyors to an air tester. At the entrance to this machine the cans are picked up by rubber vacuum pads, two at a time, and placed in pockets arranged horizontally on a large revolving wheel.

> After the cans are placed in the pockets, rubber pads seal both the pocket and can, then compressed air is admitted to the inside of the can. The area around the outside of the cans, but within the pocket, is initially at atmospheric pressure, but if the can leaks, a pressure greater than atmospheric is attained as the testing wheel revolves. At the end of the testing cycle this chamber around the can is opened to a diaphragm similar to that used in a telephone. If the can has leaked air the additional pressure in the chamber actuates the diaphragm, which operates an ingenious electrical device to discharge automatically the offending can. (Gonser, 1936).

Tested cans pass on to be stored or packed for shipment while defective cans may be repaired, or if this is not practicable, sent to the tin–plate scrap pile. Under modern can–making practice only 1 or 2 cans per 100,000 may require repair and retesting.

MANUFACTURE OF CAN ENDS

Top and bottom can ends are identical and interchangeable. They are usually made from tin plate of the same weight and thickness as that used for the body of the can. In some instances, as in certain 1–pound and ½–pound flat salmon cans, heavier plate may be used to prevent swelling of the ends in case of overfilling or insufficient vacuum. Ends are also made by the "line" system by a sub–line working in conjunction with the main or can–making line.

Sheets of tin plate are fed into the "scroll shears" machine through rotary shears which trim the sheets to the desired length, after which reciprocating feed bars transfer them to the scroll die and punch, where they are cut into strips of such pattern that they may be stamped into can ends with a minimum of waste.

The can ends are stamped out in a machine known as a "strip–feed press." The strips are stacked in the feed magazine of the strip press from which vacuum cups transfer them automatically to feed bars where they are placed accurately into position under a combination die and punch. This cuts out the can–end disc and stamps it into shape. The "expansion rings," which make the ends less resilient and aid in reducing swelling of the can ends through internal expansion, together with the groove around the edge for receiving the gasket, are also formed by the same press. The edges must still be bent over to join with the body flange, or it will be difficult to obtain a proper seam. After stamping, the can ends drop into an edge–curling attachment of the same machine. This consists of a rotary plate with a stationary outer ring. The plate constricts the edge of the end against the ring, thus turning over or curling the edge, as the ends are carried through and stacked.

The stacked ends are carried to a compound–applying machine, where they are placed in a feed magazine. The ends are fed singly to a chuck which revolves them under a jet of liquid compound, spraying a thin, even layer over the bottom of the groove around the edge. Formerly a solution of rubber in benzine was most widely used as a gasket compound but an aqueous emulsion of rubber is now preferred because it is not inflammable. The ends are then sent through a drier to remove the compound solvent or emulsifying agent.

When the gasket is completed the ends are either stacked and packed in boxes, for use in the cannery, or may be carried directly by conveyor to the double seamer in the can–making line.

STAMPED OR PRESSED CONTAINERS

"Quarter oils" mostly used in packing small sardines in oil, "half–pound ovals" used as containers for shad roe and salmon cutlets, and "1–pound ovals" used principally for packing the larger California sardines, are made by a different process. Sides and bottom ends are seamless, since they are made from a single piece of tin, deep–drawn or stamped to size. In making these cans, dies first cut the sheets of tin plate into blanks which are approximately the size of the can and sides, allowing a small margin for trimming. The blanks are fed to an automatic press or stamping machine, which consists essentially of a mold or depression in the bed of the press the size of the can to be manufactured. A punch of corresponding size is forced into the mold from above, as the blanks pass over the depression, thus "punching" or "drawing out" the can. The surplus edge by which the die holds the container in place during the stamping operation is removed by an automatic trimming machine. Then the can goes through a flanging attachment which curls the edge over into a uniform flange, so that the top may be sealed on by double seamer.

Data on the various can sizes used in packing fishery products are presented in table 6.

SHIPPING CONTAINERS

Two types of shipping containers are used for canned fishery products, the fiberboard container and wooden box. The former type was introduced into the fish–canning industry during the World War period. While not completely satisfactory at first it has been improved, and has been widely adopted by the fish–canning industry. It is estimated that fiberboard cartons now are used for at least 90 percent of the pack of all canned fish and seafoods. Wooden boxes are used only for export shipments on special order or to avoid waste when empty can–end boxes are on hand. Most can makers still ship can ends to the packer in wooden boxes, asserting that can ends packed in fiberboard cartons tend to burst the seams of the container.

WOODEN BOXES

Wooden boxes used in the domestic fishery products canning industry are entirely of the nailed type although some canned fishery products are imported in lock–corner wooden boxes.

The strength and utility of a wooden box are dependent on the weakest point in its construction. The strength of all parts should be equalized as much as possible in order to increase the average

TABLE 6.—*Types of cans used in packing fishery products*

Trade name	Can makers' description	Nominal overall dimensions of sealed cans		Capacity	Product commonly used for
		Diameter	Height		
		Inches	*Inches*	*Fluid oz.*[1]	
¼ Kanopen	211 x 109	$2\frac{11}{16}$	$1\frac{9}{16}$	3.4	Tonno
¼ Tuna	211 x 109	$2\frac{11}{16}$	$1\frac{9}{16}$	3.4	Tuna
¼ Lobster	300 x 108	3	1½	4.0	Lobster
¼ Flat	301 x 107	$3\frac{1}{16}$	$1\frac{7}{16}$	3.9	Salmon, smoked oysters, salmon paste
¼ Drawn	300.5 x 404 x 014.5	$3\frac{1}{32}$ x 4¼	$\frac{29}{32}$	4.0	Sardines, smoked salmon
¼ Narrow drawn	211 x 404 x 100	$2\frac{11}{16}$ x 4¼	1	4.22	Sardines
6 oz. Paste	202 x 309	2 2/16	$3\frac{9}{16}$	5.9	Calif. sardines
8 Z Short	211 x 300	$2\frac{11}{16}$	3	7.6	Herring roe, Calif. sardines and mackerel
8 Z Tall	211 x 304	$2\frac{11}{16}$	3¼	8.3	Herring roe, Calif. sardines, clams, clam juice
—[2]	211 x 312	$2\frac{11}{16}$	3 12/16	9.8	Clams
No. 1 Picnic No. 1 Standard or Eastern oyster	211 x 400	$2\frac{11}{16}$	4	10.5	Oysters, clams, shrimp, Calif. sardines, clam chowder, fish chowder and other soups
—[2]	300 x 210	3	2⅝	8.1	Fish flakes
No. 1 Sardine	300 x 309	3	$3\frac{9}{16}$	11.5	Creamed tuna
No. 1 Food	300 x 409	3	$4\frac{9}{16}$	15.1	Mackerel, sardines
—[2]	307 x 109	$3\frac{7}{16}$	$1\frac{9}{16}$	5.6	Shrimp (cocktail style), fish paste
½ Tuna	307 x 113	$3\frac{7}{16}$	$1\frac{13}{16}$	6.8	Tuna, tuna flakes
½ Kanopen	307 x 113	$3\frac{7}{16}$	$1\frac{13}{16}$	6.8	Tonno
No. ½	307 x 200	$3\frac{7}{16}$	2	7.7	Lobster
½ Flat	307 x 201.25	$3\frac{7}{16}$	2 5/64	8.0	Salmon, minced clams, crab, kippered shad, smoked sturgeon
½ Oblong	508 x 304 x 103	5 8/16 x 3 4/16	$1\frac{3}{16}$		Sardines
¾ Drawn	304 x 508 x 105	3 4/16 x 5 8/16	$1\frac{5}{16}$	11.0	Mustard sardines
¾ Three piece	308 x 412 x 112	3 8/16 x 4 12/16	1 12/16	11.0	Mustard sardines
½ Oval	309 x 515 x 103	3 9/16 x 5 15/16	$1\frac{3}{16}$		Salmon, Calif. sardines, shad roe
Squat	307 x 208	$3\frac{7}{16}$	2½	10.0	Shrimp, fish cakes
No. 1½, No. 95 or No. 2 Short	307 x 400	$3\frac{7}{16}$	4	17.1	Shrimp, herring roe, clam chowder, fish chowder

TABLE 6.—*Types of cans used in packing fishery products*—Continued

Trade name	Can makers' description	Nominal overall dimensions of sealed cans		Capacity	Product commonly used for
		Diameter	Height		
		Inches	*Inches*	*Fluid oz.*[1]	
No. 2 Picnic	307 x 403	$3\frac{7}{16}$	$4\frac{3}{16}$	18.0	Clams
No. 300	300 x 407	3	$4\frac{7}{16}$	14.6	Mackerel, clams
No. 1 Tall	301 x 411	$3\frac{1}{16}$	$4\frac{11}{16}$	16.0	Salmon, clams, pet food, mackerel, Calif. sardines, salt cod, Pacific oysters, shad
No. 1 Tuna	401 x 205.5	$4\frac{1}{16}$	$2\frac{11}{32}$	13.1	Tuna
No. 1 Flat (Columbia River)	401 x 210.5	$4\frac{1}{16}$	$2\frac{21}{32}$	15.1	Salmon, minced clams
No. 1 Flat (Alaska)	401 x 211	$4\frac{1}{16}$	$2\frac{11}{16}$	15.3	Salmon, clams
No. 1 Flat	404 x 206	$4\frac{1}{4}$	$2\frac{3}{8}$	15.0	Lobster
No.[2] 1 Oval	607 x 406 x 108	6 7/16 x 4 6/16	1 8/16		Calif. sardines, salmon, shad roe, mackerel, sea herring
No. 303	303 x 406	$3\frac{3}{16}$	$4\frac{3}{8}$	16.2	Clam chowder
No. 2	307 x 409	$3\frac{7}{16}$	$4\frac{9}{16}$	19.7	Clams, clam chowder, oysters, Dungeness crab, alewives (river herring)
Jumbo or No. 307 Cylinder	307 x 510	$3\frac{7}{16}$	$5\frac{5}{8}$	24.8	Clam chowder
No. 2 Tall	307 x 604	$3\frac{7}{16}$	$6\frac{1}{4}$	27.7	Alewives (river herring)
No. 2½	401 x 411	$4\frac{1}{16}$	$4\frac{11}{16}$	28.6	Clams, clam chowder
No. 3	404 x 414	$4\frac{1}{4}$	$4\frac{7}{8}$	33.7	Clams, clam products
No. 5	502 x 510	$5\frac{1}{8}$	$5\frac{5}{8}$	56.7	Clam chowder, shrimp
4 lb. Tuna	603 x 408	$6\frac{3}{16}$	4 8/16	65.4	Tuna, salmon
No. 10	603 x 700	$6\frac{3}{16}$	7	105.1	Clam chowder, pet food, Calif. sardines

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[1] The capacity figures given are the maximum theoretical capacities in terms of fluid ounces and are not a recommended fill for any product. The actual capacity of any individual can may vary slightly from this calculated value because of differences in style of construction and because of necessary tolerances in manufacture and closure. Similar factors affect the nominal dimensions derived from the can makers description.

[2] No trade name.

strength of the container. Cruess (1938) lists the cause of failure in wooden boxes as: (1) Too few nails; (2) too large nails; (3) too small nails; (4) driving the nails too near the edge of the boards; (5) over–driving the nails; (6) use of ends too thin to hold the nails; (7) ends of boxes not properly reinforced; (8) use of too thin pieces for sides, top or bottom; (9) use of wrong species of wood; (10) use of too many pieces; and (11) use of unseasoned lumber.

The advantages of the wooden box are: (1) It is easier to pile and may be stored in higher stacks; (2) has greater resistance to puncture; (3) is less liable to damage from moisture; and (4) has a re–use value not possessed by the fiberboard carton, an important consideration in some markets.

The chief disadvantage of the wooden box is that it is more expensive. The standard wooden case holding 48 one-pound cans costs an average of 18 cents, while a fiber carton of the same size has an average cost of 12 cents. The wooden case is heavier than the fiber case and the outside overall measurement is greater, thereby increasing freight and handling costs.

Box lumber should be free from pitch, straight–grained and relatively free from knots. The moisture content should not be more than 15 percent. The ends should be planed and made of material that takes a good ink impression so that a design may be printed on them. In the Pacific Northwest and in Alaska, spruce is specified as the material when available. But little spruce is being cut now and hemlock must be used for the most part although it is considered less satisfactory. It is estimated that of the box lumber used by canners in the Pacific Northwest area, 25 percent is spruce and 75 percent hemlock. In California, western yellow pine, also known as white pine, is used as box material. In the New England Area the eastern white pine is the most important local source of box lumber, while in the Gulf and South Atlantic States southern yellow pine is used. Some gum and tupelo are made into boxes for canned products in the Southern States.

Such materials as oak, hickory and other hard woods are rarely used in making boxes for canned goods because they require very sharp tools in manufacturing into box boards, are more troublesome to handle, and are difficult to nail. Hemlock is believed to be the most important lumber for the comparatively small amount of wooden boxes used in the fishery–products canning industry today. Ends for wooden boxes should be made of a single piece and the sides and bottom should consist of not more than two pieces. End boards should be not more than one-half inch thick and the sides and bottom one-quarter inch thick (Cruess, 1938).

TABLE 7.—*Dimensions of wooden boxes for canned fishery products*[1]

Trade name	Can makers description[2]	Cans per box	Arrangement of cans			Inside dimensions of box[3]		
			Number in row	Number of rows	Number of layers	Length	Width	Depth
						Inches	*Inches*	*Inches*
6 oz. paste	202 x 308	48	6	4	2	12⅞	8⅝	7⅛
8 Z Short	211 x 300	48	6	4	2	16⅜	11	6⅛
8 Z Short	211 x 300	72	6	4	3	16⅜	11	9⅛
8 Z Tall	211 x 304	48	6	4	2	16⅜	11	6⅝
8 Z Tall	211 x 304	72	6	4	3	16⅜	11	9¾
No. 1 (Picnic)	211 x 400	48	6	4	2	16⅜	11	8⅛
No. 300	300 x 407	48	6	4	2	18¼	12⅛	9
No. 1 Tall	301 x 411	48	6	4	2	18½	12¼	9½
No. 303	303 x 406	24	4	3	2	12⅞	9¾	8⅞
No. 303	303 x 406	48	6	4	2	19¼	12⅞	8⅞
No. 2	307 x 409	24	4	3	2	13⅞	10½	9¼
No. 307 Special	307 x 510	24	4	3	2	13$\frac{15}{16}$	10½	11⅜
No. 2 Tall	307 x 604	12	4	3	1	13$\frac{15}{16}$	10½	6⅜
No. 2 Tall	307 x 604	24	4	3	2	13$\frac{15}{16}$	10½	12⅝
No. 2½	401 x 411	24	4	3	2	16⅜	12¼	9½
No. 3	404 x 414	24	4	3	2	17$\frac{3}{16}$	12$\frac{13}{16}$	9⅞
No. 5	502 x 510	12	3	2	2	15$\frac{9}{16}$	10⅜	11⅜
No. 5	502 x 510	12	4	3	1	20$\frac{11}{16}$	15$\frac{9}{16}$	5¾
No. 10	603 x 700	6	3	2	1	18¾	12½	7

[1] These specifications are adapted from "Simplified Practice Recommendation R 171-38." National Bureau of Standards.

[2] Under the heading "can makers' description" the first 3 figures represent the outside diameter of the can, and the second group of 3 figures represents the height of the sealed can. The first digit of each group represents "inches" and the second and third digits of each group represent "sixteenths of an inch" (Example: 211 x 400 means the diameter is 2$\frac{11}{16}$ inches and the height is 4 inches).

[3] The inside dimensions of boxes as shown above do not contemplate the use of a liner between layers of cans. All dimensions stated are net. If dividing liners between tiers of cans are used, the dimensions shown for depth of box should be increased by the thickness of the particular liner or series of liners used.

The specifications of wooden boxes used in packing canned fishery products are listed in table 7.

FIBERBOARD BOXES

The fiberboard used in making boxes for fishery products packed in tin is of the solid type, while boxes used for products packed in glass are made of corrugated material. Solid fiberboard is made up of a series of sheets of heavy–weight high–test paper cemented together with sodium silicate. The individual sheets average upwards from 0.016 inch in thickness. The board is made in three standard thicknesses for canned goods containers; namely, 0.080, 0.090, and 0.100 inch, known as "80–point," "90–point" and "100–point" board. The common practice in the fish–canning industry is to require 100–point board for the standard case of 48 one–pound talls while smaller packages such as the cartons holding 48 No. 1 picnic, or 24 twelve–ounce cans are made of 80– or 90–point board.

Corrugated board is made of a center layer of thin straw paper with its surface bent in a series of waves like the corrugations of a wash board. The air spaces produce a cushioning effect in this type of fiberboard container, making it especially suitable for products packed in glass.

The advantages of the fiberboard case are: (1) It is less expensive; (2) it is lighter, making the cases easier to handle and reducing the freight cost; (3) the cubic measurement is sufficiently smaller than that of the wooden container to constitute an additional economy factor in shipping; (4) it provides a much better medium for printing and lithographing, thus augmenting the advertising value; (5) knocked–down containers are more easily stored and handled; and (6) the amount of loss through theft is generally less when fiberboard cartons are used, because tampering is more readily detected.

The disadvantages of the fiber case are: (1) It is less resistant to puncture than the nailed wooden box; (2) it has less resistance to damage through becoming water soaked by rain, or under other conditions where it may be attacked by moisture over a long period of time; (3) it is more difficult to stack than the nailed wooden box; and (4) the individual container has less resistance to pressure from other cases in the stack than the wooden box, and fiber containers in the lower layers may be weakened by pressure if the stack is piled too high.

The specifications of fibreboard cases for canned fishery products are listed in table 8.

The fiberboard container is cut to size, folded into shape and printed with any desired design or legend by the container manu-

TABLE 8.—*Dimensions of fiberboard boxes for canned fishery products*[1]

Trade name	Can makers' description[2]	Cans per box	Arrangement of cans			Inside dimensions of box[3]		
			Number in row	Number of rows	Number of layers	Length	Width	Depth
						Inches	*Inches*	*Inches*
6 oz. paste	202 x 308	48	6	4	2	12¾	8½	7
8 Z Short	211 x 300	48	6	4	2	16 3/16	10 13/16	6
8 Z Tall	211 x 304	36	4	3	3	10 13/16	8 1/16	9¾
8 Z Tall	211 x 304	48	6	4	2	16 7/32	10 13/16	6½
No. 1 Picnic	211 x 400	48	6	4	2	16¼	10 13/16	8
No. 300	300 x 407	36	4	3	3	12⅛	9⅛	13⅜
No. 1 Tall	301 x 411	48	6	4	2	18⅜	12¼	9⅜
No. 303	303 x 406	24	4	3	2	12¾	9 9/16	8¾
No. 303	303 x 406	36	4	3	3	12¾	9 9/16	13⅛
No. 303	303 x 406	48	6	4	2	18 1/16	12	8⅞
No. 2	307 x 409	24	4	3	2	13¾	10 5/16	9⅛
No. 307 Special	307 x 510	12	4	3	1	13 13/16	10⅜	5⅝
No. 307 Special	307 x 510	24	4	3	2	13 13/16	10⅜	11¼
No. 2 Tall	307 x 604	12	4	3	1	13 13/16	10⅜	6¼
No. 2 Tall	307 x 604	24	4	3	2	13 13/16	10⅜	12½
No. 2½	401 x 411	24	4	3	2	16¼	12 3/16	9⅜
No. 3	404 x 414	24	4	3	2	17 1/16	12 13/16	9¾
No. 5	502 x 510	12	3	2	2	15 7/16	10¼	11¼
No. 5	502 x 510	12	4	3	1	20 9/16	15 7/16	5⅝
No. 10	603 x 700	6	3	2	1	18⅝	12⅜	7

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[1] These specifications are taken from Simplified Practice Recommendation R 146-38. National Bureau of Standards.

[2] Under the heading "can makers' description" the first 3 figures represent the outside diameter of the can, and the second group of 3 figures represents the height of the sealed can. The first digit of each group represents "inches" and the second and third digits of each group represent "sixteenths of an inch" (Example: 211 x 400 means the diameter is 2 11/16 inches and the height is 4 inches).

[3] The inside dimensions of boxes as shown above do not contemplate the use of a liner between layers of cans. All dimensions stated are net. If dividing liners between tiers of cans are used, the dimensions shown for depth of box should be increased by the thickness of the particular liner or series of liners used.

facturer. Knocked–down cases are shipped to the packer in bundles. They are reformed at the cannery and the bottom is fastened with adhesive, gummed tape or staples. The can makers prefer the bottom to be "sewed" or stapled, and this is also recommended to packers of fishery products. The efficiency of sealing with adhesives depends on the quality of adhesive, the dependability of the labor, and on the scoring or folding of the sides. One of the principal causes of failure of hand–sealed boxes has been traced to careless or inefficient labor. Sealing machines usually do a better job than hand labor. If the sides are not properly folded at the edges, the top and bottom flaps do not make good contact so it is impossible for the adhesive to perform its function. Sodium silicate is extensively employed as an adhesive, especially in machine sealing but many packers prefer one of the commercial hot–water glues. Some packers claim that sodium silicate dries too rapidly and that poor sealing occurs when hand sealing is employed.

IMPORTANT FACTORS IN THE OPERATION OF CANNING MACHINERY

Manufacturers' catalogs contain elaborate lists of machinery and equipment which might lead one to believe that a very extensive outfit is invariably required. The types and number of units of equipment necessary depend on the volume of production, type of pack, availability of skilled labor and arrangement of machinery. A short description of the most important factors in the operation of the types of equipment in general use is presented since this information is not contained in canning machinery catalogs or other manufacturers' handbooks customarily available for reference. However, a detailed discussion of the various pieces of machinery used in special fish canning operations is not within the scope of this publication.

BUTCHERING OR CLEANING MACHINES

Butchering or cleaning machines include all equipment used in removing heads, fins, viscera and other waste from raw material, and in freeing it from blood, slime, scales or dirt. Complete mechanical equipment for this step has been developed only in the salmon canning industry. In the canning of other fishery products machines have been designed for performing single functions such as scaling the body, or removing the head or intestines.

Among the reasons given for not completely mechanizing the process in packing products other than salmon are: (1) Low cost of hand labor in some districts, so that no saving would occur; (2) inability to handle small fish such as the Maine sardine; (3) non-symmetrical shape, so that loss of weight in trimming is greater with mechanical equipment; (4) damage to texture of flesh; and (5) difficulty of financing and marketing such devices.

The butchering tables should be of proper height so operators may work with as little fatigue as possible. They should be sufficiently wide so that raw material will not accumulate excessively, thus clogging operations. The top surface of the tables should be of durable non-corroding metal to reduce the amount of raw–material contamination.

Butchering machines require regular care and frequent adjustment since dull cutting knives tear the flesh, do not make a clean cut, adversely affect the appearance and do not completely remove the fins. A definite schedule cannot be set for resharpening knives since it depends on the variety of fish, amount of time the machine is in operation, amount of slime on the fish, amount of silt in the water and whether fresh or salt water is used on the machine. A good general rule is to hone the knives at least once daily, and refile at less frequent intervals.

The adjustment of saws used in butchering operations, such as removing the tails and fins, or opening the body is very important. If not set properly, the butchering will be ragged, with waste of raw material. A stream of water, sufficient to keep all gurry and scales flushed away, should be played on knives and saws used in finning, splitting, or trimming the fish. This material has a tendency to collect around the saws thus slowing the machine as well as making a poor job of the butchering.

The large amount of blood, slime and viscera removed from fish makes thorough and frequent cleaning of the machine especially important, because a carelessly operated machine offers increased opportunity for contamination of the product. Cleaning should not be confined to removal of adherent waste material. After flushing the machinery thoroughly with a stream of water under heavy pressure, a steam hose should be used to scald and dry all parts. Grease- and oil-cups should be filled and the machine carefully inspected at the end of each day's operation.

The manual issued concerning the care of the "iron chink" (McKee, 1927) should be studied carefully by every salmon canner, and by other fish canners as well, since it contains information of general value in mechanical butchering. The operation of the iron chink is described in detail in the discussion of canning salmon.

With an increase in labor costs, it is to be expected that more attention will be paid to mechanical butchering and cleaning machinery than in the past, and that equipment will be developed for use with products where the operation is now carried out by hand.

PRECOOKING OR PREPARATION MACHINES

Equipment for precooking or other preparatory operations is highly specialized and widely different types of machines may be used in packing a single product. Preparation machinery includes fish–cutting machinery, grinders, peelers and slicers (as in cutting potatoes for fish cakes or chowder), beaters and mixers, steam–jacketed kettles, blanching tanks, fry baths, baking ovens, and steam chests.

Because of the specialization and the lack of uniformity in equipment of this type, the canner should be very careful in purchasing machinery for precooking or preparation. It is advisable to visit as many canneries packing the same product, or similar products, as possible, observing preparation equipment in action, discussing the advantages and disadvantages of different machines before purchasing equipment.

Preparation equipment devised in the cannery should be thoroughly tested on an experimental scale before it is used in commercial production. If this is not done, expensive apparatus must sometimes be junked after very little use, and portions of the pack discarded, or at least it will be damaged in quality. The research and engineering departments of the large can–making or canning–machinery companies usually may be relied on for advice as to the practicability of machinery. Sometimes these manufacturers will assist in developing improvements in preparation or precooking equipment.

CAN–CLOSING MACHINES OR DOUBLE SEAMERS[3]

MACHINE PARTS IN THE CLOSING MACHINE

Double–seaming machines made by different manufacturers vary extensively in appearance, design, speed of operation and a number of other details. All have in common, however, certain units essential to the manufacture of the double seam, which closes the ends of the can.

1. The seaming head, a very important unit of the machine, carries the seaming rolls, cams, and gears which rotate the rolls about the top of the can, causing them to approach the chuck and recede in proper sequence.

2. First–operation rolls are mounted on the seaming head. Usually a seaming head carries two first–operation rolls placed in diametrically opposite position but working in unison to achieve mechanical balance of the rapidly revolving seaming head and to equalize strains.

3. Two second–operation rolls are carried by the seaming head for the same reason that the two first–operation rolls are used, namely to equalize strains and for mechanical balance. The two sets of rolls are mounted on the two diameters of the head at a 90° angle from each other. When the first–operation rolls are functioning and are nearest the chuck, the second–operation rolls are at their outer limits of travel.

4. The seaming chuck is a hardened and ground steel disk that lies at the center of the seaming head between the rolls. The

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[3] This section was prepared by Lynne G. McKee, Associate Technologist, Division of Fishery Industries, Fish and Wildlife Service.

chuck is screwed to the chuck spindle, a hollow spindle which extends upward to the top frame of the machine and is locked rigidly in place by two lock–nuts which permit the chuck to be raised or lowered with reference to the seaming rolls. The seaming head, and the hollow quill, which carries the head, revolve around and are independent of, the chuck spindle, which is stationary. The function of the chuck is to fit firmly within the countersink of the top of the can, furnishing a positive backing for the seaming rolls and regulating the depth of the seam.

5. The plunger, a device which brings the can up to, and in firm contact with, the seaming chuck. The plunger contains within it the compression spring or springs. It is capped with the "plunger plate," a hardened–steel corrugated plate with side gibs which engage the bottom seam of the can and withdraw the seamed can from the chuck.

6. The knockout rod is necessary because when the tops are not clinched on the can before passing through the exhaust box, the top is applied to the can on entering the seamer. Some means must be provided to hold the top on the can, or it will be displaced by the sudden rise of the plunger. The knockout rod drops down onto the loose top and holds it in place until the can is in firm contact with the chuck.

7. The turret, or other timing device, holds the can firmly while passing through the machine, and places it centrally in position, under the chuck and on the plunger plate. The can is held in position until the seaming operation is completed and the can again is lowered by the plunger.

FORMING THE DOUBLE SEAM

The double seam is formed in two distinct operations. The "first operation" is performed by the "first operation rolls" (fig. 6). These rolls have a narrow, deep, and highly polished groove around the circumference. This groove serves to properly shape, or roll together the edge of the can top and can body, in preparation for the final or second operation which completes the seam. The "second operation" flattens, under rolling pressure, the bead of first roll produced on the can by the first operation rolls by means of the wide, shallow and highly polished grooves of the second operation rolls (fig. 6). Both sets of rolls are of hardened and polished steel, turned and ground to exact dimensions. They are manufactured within exact limits in order that worn–out rolls may be replaced with a minimum of adjustments.

If the cans are to be passed through an exhaust box before seaming, it is often the custom to clinch the top lightly onto the can before it enters the exhaust box. This operation is performed by a machine known as the "clincher." In passing through the machine, a top is wiped off the bottom of the stack of tops in the magazine, and dropped onto the can of filled product. A cam-actuated plunger moves downward onto the top of the can, holding the top firmly in place, while the edge of the top is rolled slightly under the flange of the can body (see fig. 6). This operation prevents the top from falling off the can while passing through the exhaust box, yet allows the heated vapors to escape freely. In many cases the tops are applied directly to the cans at the seamer (closing machine), the cans passing through the exhaust box without covers.

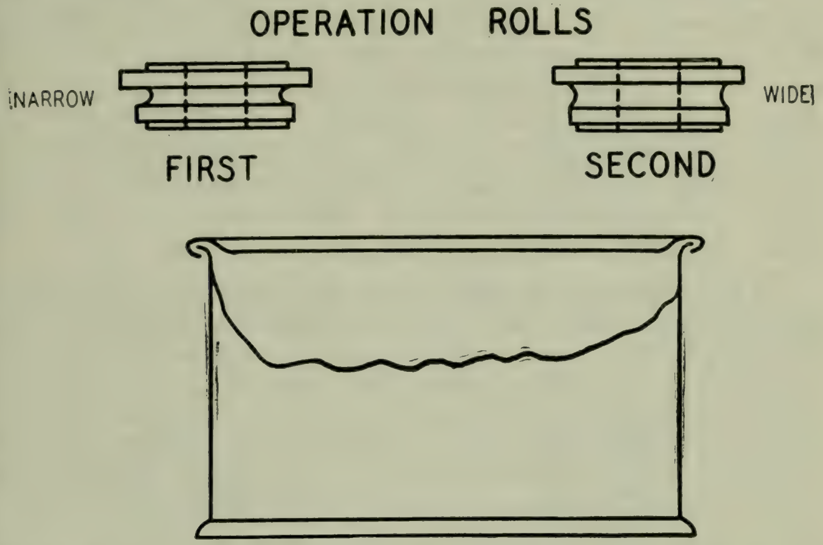


FIGURE 6.—Can sealer rolls (above) and sketch of can (below) showing different parts (L. G. McKee).

Immediately after leaving the exhaust box the cans are passed into the turret or timing device of the double seamer. Here the can is held firmly in place and is passed onto the "plunger" which is below, and in line with, the seaming chuck. As soon as the turret has carried the can onto the plunger, the plunger rises and forces the counter sink of the can top onto the seaming chuck. The can is held there throughout the seaming operation. The plunger face is fitted with a corrugated-steel plate. These corrugations on the plunger plate bite lightly into the bottom seam of the can and prevent the can from rotating while being seamed. This is necessary as both first- and second-operation rolls have an appreciable rotating effect on the can while it is being seamed.

If the plunger plate should become worn, and the corrugations lose their bite on the bottom seam of the can, the can will spin on the chuck causing what is known as a "skid" and resulting in an incomplete seam.

The plunger is fitted with a compression spring or springs which compensate for slight variations in the heights of cans and produce a constant tension on the cans against the chuck while they are being seamed. These springs may allow the plunger to compress, when at its greatest height, as much as 3/32 inch, depending on the make of seamer. This compression adds sufficient tension to hold the can firmly in place during the seaming operation. A fixed plunger with no compression springs, or one in which the springs are inactive due to caked dirt in the coils, would force a can of slightly greater than normal height so firmly against the chuck so as to result in crumpling the side walls of the can body. The metal of the top seam might also be forced over the top of the chuck, forming what is called a "cutover." A cutover results when a little of the metal of the top seam, (usually above the side seam where there is excess metal) is forced over the top edge of the chuck. As the plunger drops and withdraws the can from the chuck, this bit of cutover tears out, leaving a leaky seam.

If a can should be of slightly less than normal height, and the seamer plunger have inoperative compression springs, the can would not be held firmly against the chuck, and would spin under the action of the seamer rolls. The seam, if formed, would be narrow or, which is more likely, incomplete. If a can does not remain stationary throughout the entire seaming cycle, the seam will not be completed. "Skids," formed as a result of such a condition, may be recognized by the incomplete second roll seam, and by the shiny, filed appearance of the bottom of the seam on the base of the can where it has slipped or "skidded" over the corrugations of the plunger plate.

The various operations in seaming occur in the following sequence:

The can with the top loosely clinched emerges from the exhaust box and enters a pocket of the turret of the double seamer. The turret, in rotating, eventually brings the can onto the plunger and exactly under the seaming chuck. Immediately, the plunger rises and forces the can top onto the seaming chuck. The instant the plunger starts to rise the knockout rod has dropped down and touched the can top lightly, holding it in place until the can is against the chuck. Both the first and second rolls are inoperative at this instant, and are at the outer limits of their orbits, spinning about the chuck, idle. When the plunger has reached the upper limit of its stroke and the compression springs have taken effect, the first operation rolls close in. At their nearest point of approach to the chuck, they have completed the "first roll" or partial seam (fig. 7).

The first rolls now recede and the second operation rolls approach the chuck, and in a like manner flatten down or iron out the bead or "first roll," compressing the layers of metal firmly and makes a tight seam (fig. 7). When the plunger drops downward the gibs on the side of the corrugated plunger plate engage the bottom seam of the can and withdraw it from the chuck. The knockout rod follows the can down. As soon as the can has reached its former level the turret moves one step forward, removing the completely sealed can from the plunger, and bringing another can under the chuck for seaming.

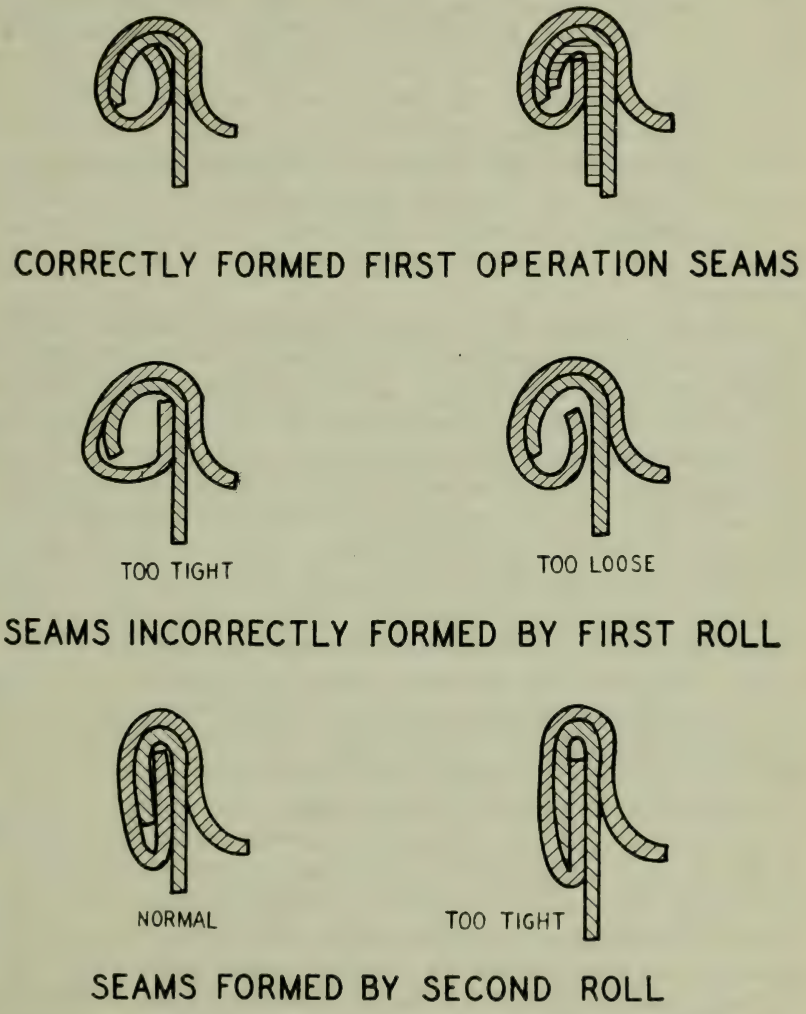

CORRECTLY FORMED FIRST OPERATION SEAMS
TOO TIGHT
TOO LOOSE
SEAMS INCORRECTLY FORMED BY FIRST ROLL
NORMAL
TOO TIGHT
SEAMS FORMED BY SECOND ROLL

FIGURE 7.—Correctly and incorrectly formed can seams (L. G. McKee).

The dimensions of a correctly–formed double seam will differ slightly with each can manufacturer and according to the size of cans being seamed. With the majority of food containers on the market the dimensions of the seams as shown by the can–seam gauge in figure 9 are approximately correct.

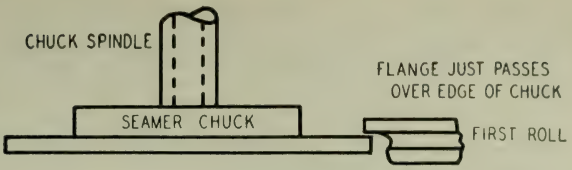
ADJUSTMENT OF SEAMING HEADS

Adjustment of the seaming heads depends upon, and varies with, manufacturers' instructions for each different make and type of seamer. Double seaming cannot be reduced to a general formula. However, the following points will be found applicable to most seaming heads.

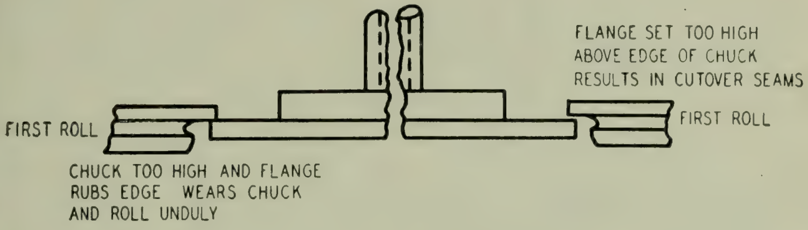
Some seaming heads are so constructed that the second roll pins can be rotated to an "off–position," and it is not necessary to remove the second rolls when adjusting the first rolls. With the second rolls removed, or on the off–position and out of the way, turn the machine by hand until the first rolls are at their nearest point to the chuck. This is usually just before the first rolls are ready to recede. See that the chuck has been lowered by means of the adjusting nuts, so that the flange of the rolls, just above the groove, will slip over the upper edge of the chuck disk without rubbing.

When the rolls are at their innermost point, gradually raise the chuck by adjusting nuts until the chuck just touches the roll flange (fig. 8). Turn each roll with the fingers to insure that the roll flange is not rubbing hard enough on the chuck to cause wear. It should turn freely and yet show no space between the roll flange and upper edge of chuck. If there is any appreciable opening here, the metal of the can top will be rolled slightly over the top edge of the chuck. Figure 8(A) shows a roll set too high. "Cutovers" are caused by rolls set too high. If the chuck should be set too high the roll flanges will rub the edge of the chuck severely and in a short time the rolls and chuck will have to be replaced. Figure 8(B) shows a roll set too closely to the chuck. When testing first operation rolls for clearance see that both rolls are the same distance from the chuck; otherwise, one roll will rub the chuck edge while the other one may still be free.

In setting rolls for the proper distance of the groove from the chuck face, use can be made of the test wire (fig. 9). This wire which, for instance, may be .087 inches in diameter should be inserted into the roll groove and then the chuck face. Set the rolls so that a firm steady pressure must be exerted to insert and withdraw the wire. Endeavor to equalize the pressure on the rolls so that each will be doing the same amount of work during the seaming operation.



CORRECTLY ADJUSTED FIRST OPERATION ROLL


FLANGE SET TOO HIGH ABOVE EDGE OF CHUCK RESULTS IN CUTOVER SEAMS
FIRST ROLL
FIRST ROLL
CHUCK TOO HIGH AND FLANGE RUBS EDGE WEARS CHUCK AND ROLL UNDULY

INCORRECTLY ADJUSTED FIRST OPERATION ROLL

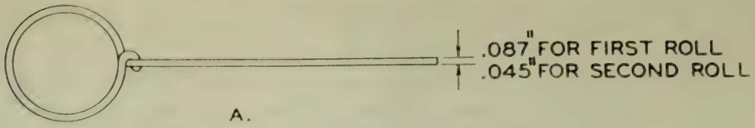
(MISALIGNMENT IS EXAGGERATED)

FIGURE 8.—Correctly and incorrectly adjusted can-sealer rolls (L. G. McKee).

When the first rolls apparently are set correctly an empty can with top may be run through the machine, preferably by hand. Since the second rolls are in the "off–position," or are removed entirely, the result of the first rolls only will be observed. The metal of the top should be tucked up closely against the can body forming an almost round bead. It should not be so tightly rolled as to be almost solid or like a piece of wire.

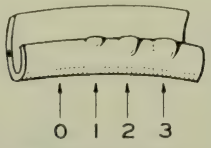
If the "first roll" or operation is found satisfactory, the second rolls may be set in seaming position. The procedure followed is practically the same as for the first operation rolls. The height of the chuck when set properly for the first rolls should also be correct for the second operation rolls. Some of the older types of closing machines had thin shims introduced between the roll pin and the housing of the seaming head so that the second rolls could be given proper clearance. This makeshift device is not found in modern machines, and a proper allowance is made for clearance when the roll is machined.

With proper adjustment for chuck height already made, the second rolls need only be set up for seaming. Turn the machine by hand until the second rolls are their closest point to the chuck. This occurs an instant before seaming is completed and the plunger is ready to drop withdrawing the can from the chuck. Check each roll to see that pressure is correct and equalized be-



A.

A TEST WIRE OR GAUGE FOR PRELIMINARY
SETTING OF SEAMER ROLLS



DESCRIPTION

0 - SMOOTH, NO WAVES
1 - WAVY UP TO 1/3 DISTANCE FROM EDGE
2 - WAVY FROM 1/3 TO 1/2 DISTANCE FROM EDGE
3 - WAVY MORE THAN 1/2 DISTANCE FROM EDGE

B.

WAVES IN COVER HOOK OF CAN LID

FIGURE 9.—Test wire and waves in cover hook of can lid.

tween the rolls, using the second roll adjusting wire which may be 0.045 inches in diameter (depending on the make of seamer). Do not depend entirely on the test wire for final adjustment. The appearance of the seam should be carefully noted. First one, then the other second roll may be removed and cans run through the machine to check independently the completed seam formed by each roll. Finally, test the finished seam formed by both sets of rolls.

VISUAL INSPECTION OF CAN SEAMS

A flat file with a safe edge, and a small magnifying glass are required for the visual inspection of double seams. According to the American Can Co. (1934) the file should be so held that the safe edge is against the proposed cross section. This will minimize the tendency to procure a burr on the tin.

A seam is opened for inspection as follows. Make two file cuts through the double seam into the body of the can, about an inch apart, and slightly to the left of the side seam. Then file through the first thickness of tin between the file cuts. By tapping the edge of the file on the side of the filed section, this portion can be knocked downward and removed. Thus the inner side of the hook on the can top may be inspected, as well as the body hook. If the can is properly seamed a very light wrinkled effect should be noted on the can top and body hooks. If wrinkles are entirely ironed out the rolls are tighter than necessary, and the metal may have been stretched and subjected to unnecessary strain. If wrinkles are quite prominent the rolls are not tight enough and the seam may be defective.

The can body hook may be measured by a can seam micrometer which will give the depth of body hook in thousandths of an inch. The body hook should measure between 0.075 and 0.085 inches in depth. A good seam will not be formed if the hook does not fall within these limits. An uneven body hook on opposite sides of the can may indicate that the can is not coming up squarely onto the chuck, necessitating a thorough check up on the machine. If the body hook exceeds 0.085 inches to any great extent, the can top will not have sufficient hook to make a tight seam. If the body hook is shorter than the lower limit permissible, namely 0.075, it is much too short for a good seam.

SEAM GAUGES

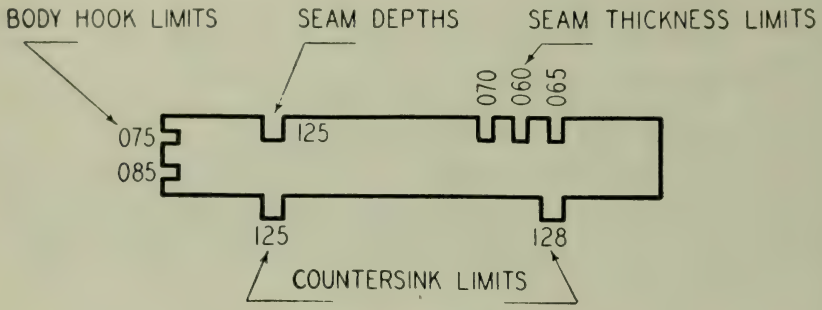
Manufacturers of cans and seamers will usually supply seam gauges to the packer as an aid toward good seaming. Safe limits are indicated for the particular seamer and can being used, by means of the "go" and "no–go" slots in the can gauge. The dimensions given above do not apply to all can sizes or all seamers, but they are approximately correct for most cans used in the commercial food canning industry.

One type of can–seam gauge is illustrated in fig. 10. The slots marked 0.075 and 0.085 are the upper and lower limits of the can–body hook. One slot on the side marked 0.125 is the depth of the completed seam. The three slots marked 0.060, 0.065, and 0.070 are "go" and "no–go" gauges for the thickness of the seam as measured across the top of the can. The two extensions marked 0.125, and 1.28 are limits for the depth of the counter-sink of the can top. Any marked deviations from these limits are for the depth of the counter–sink of the can top, and if such deviations are noted in the can a check up on the seaming mechanism is indicated.

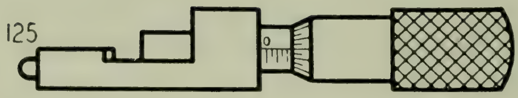
The greatest margin of safety is obtained by adhering to the standard dimensions. A double seam may deviate from standard dimensions and a hermetic seal obtained, but the possibilities of loss are greatly increased. If poor seaming permits the entry of micro–organisms, attention paid to sufficiency of process is wasted, and the product will be spoiled.

LUBRICATION

Proper lubrication is of the utmost importance. In addition to their high speed, seaming heads operate under considerable strain. Check carefully with the manufacturer on the amount and grade of grease or oil to be used, particularly in gear cases, seaming head spindles, and roll pins. Check the lubrication of the machine at the start of the day's operations, several times during the day, and at the close of the day.



CAN SEAM GAUGE



CAN SEAM MICROMETER

FIGURE 10.—Can seam gauge and micrometer.

CONCLUSION

This discussion has attempted to describe briefly the structure of a double seam, and factors in the operation of double seamers (closing machines) necessary to the obtaining of a safe hermetic seal. Seamer–operators should become thoroughly familiar with the adjustments of the particular machine they are operating and the correct dimensions of a perfect seam for the particular can or cans in use. Modern seamers run at high speed and do not necessarily remain in perfect adjustment, so that test cans should be taken frequently from the seamer and the seam opened for inspection. A safely sealed product requires constant vigilance.

CAN WASHERS

Until 1920 cans usually were washed only after processing. The equipment was simple, consisting of two shallow metal tanks located near the retorts; slat– and chain– or bar–conveyors, slightly narrower than the tank width, ran through the tanks which were connected. This washer, known as the "lye wash" contained a strong alkaline cleansing solution in the first tank, while the second held hot fresh water. The equipment was developed in the salmon canning industry, where it is still in use.

It was necessary to use a strong cleansing solution, since fragments of fish, oil, or other undesirable materials accumulated on the outside of the container during filling and sealing, and were baked on in the retort while processing. This increased the liability of the outer surface toward corrosion, especially after the practice of lacquering was abandoned. Tanks were made locally out of any material at hand; they were apt to break down, and the rate of speed of the conveyor was not always constant. The advantage of this washer is that where cans are stacked in shallow trays, or "coolers," in a single layer, greater rapidity of handling is possible.

Lye wash tanks now are made by canning machinery manufacturers according to standard specifications. Light-weight cans and leaks are detected readily in a washer of this type because the former float and bubbles rise from leaky cans.

The first change in can–washing procedure was to install additional can washing equipment usually placed on the canning line immediately following the "clincher," making it possible to use a weaker cleaning solution after processing. This washer consists essentially of a box-like metal housing containing perforated pipes on each side of the conveyor, adjusted so that jets of water at strong pressure strike the sides of the can. Most of the particles of flesh or liquids clinging to the outside of the can are easily removed by a strong spray of water before the container enters the retort.

A more recent innovation is the installation of can washers, following the closing machine or double seamer, eliminating washing after processing. These washers ordinarily consist of steep narrow tanks of sheet metal divided in two sections, the first containing a cleaning solution, the second rinsing water. Individual cans roll down conveyors from the closing machine, through the soapwater where a mechanically–operated brush scrubs the can surface, then into the rinsing water and finally down an incline into the retort basket.

A new can washer of this type which apparently is very satisfactory has been developed at Monterey, Calif. This washer is a wheel 40 inches in diameter revolving in a sheet–metal tank. Stiff–bristle brushes are fixed all around the rim. Perforated steam pipes are placed in the tank below the wheel, serving the double purpose of heating the wash water, and acting as guides. The cans are carried by conveyor from the closing machine to the washer. Here they roll down the guides into the tank of hot soap solution, and pass out the other side. The wheel and guides are spaced so that the brushes scrub the cans thoroughly but do not retard the dropping into the retort basket. This washer handles 185 cans per minute.

Poor can washing is still responsible for some of the trouble caused by corrosion. Some of the difficulties in labeling may be traced to faulty can washing, and if cans are dirty, examiners are inclined to inspect closely them for other evidences of poor workmanship in packing.

RETORTS OR COOKERS

Two types of retorts or cookers are used generally in the processing of fishery products. Both operate with steam under pressure. The open hot water bath is only used in the pasteurization of caviar and seafood cocktails. It cannot be used where commercial sterility is required. The agitating cooker is used in a single fish cannery.

VERTICAL RETORTS

Vertical retorts are often much smaller than the horizontal type and have an average diameter of 3 feet and a height of 6 feet. They are upright cylinders of iron or steel, and may be sunk below the cannery floor for half their height, or set entirely above the floor level. Where a portion of the retort is below floor level the labor required in operation, and the amount of lift required from the mechanical hoist is reduced, but it is more difficult to adjust or repair.

The advantages claimed for the vertical retort are that it is more economical in steam utilization and that, because it can be loaded in a shorter time than the horizontal type, there is not so much likelihood of deterioration of the product through delays in processing.

The disadvantages of the vertical retort are that it is not as well adapted to large scale production as the horizontal type and that because the top is held in place by a series of swing bolts which must be operated manually, there is the possibility of faulty closing, which may affect processing.

Vertical retorts are operated in a straight row, or in a semi-circular battery of several cookers. Cans are placed in large metal baskets which are hoisted into the retort by an overhead traveling crane, usually operated by steam or air pressure, although electric hoists are coming into use. In a few of the smaller and older plants the baskets are lifted by block and tackle. A can crate may be of such a size that a single basket will fill the retort, but the more usual custom is to have three baskets to the retort.

HORIZONTAL RETORTS

In the fish–canning industry of the Pacific Coast and Alaska the horizontal retort is used almost to the exclusion of the vertical type, although few horizontal retorts are found along the Atlantic Coast. Horizontal retorts are of two varieties, of which the first is the "Portland" retort, an oblong steam chest of medium–weight boiler plate, with a door held in place by a series of swing bolts. The capacity is small, usually not more than one car holding 6 trays. The second, or Pacific–Coast type, is cylindrical in shape, is from 10 to 20 feet in length and 5 feet in diameter, of heavy steel construction, and has doors made to lock by turning a large handwheel in the center of the door. For the last few years horizontal retorts have been made with doors at each end, increasing the efficiency of operation and reducing the amount of labor required in processing.

AGITATING COOKERS

Theoretically, in processing "border–line" products such as crab meat or minced razor clams, agitating cookers, either continuous or non-continuous, will give greater sufficiency of process, without adversely affecting the quality of the product, than the usual type of retorts. Although agitating cookers are widely used in canning milk and certain fruit and vegetable products, and some research work has been conducted on the processing fishery products in this type of retort, in 1938 it was used commercially in only a single plant.

The greater operating cost due to the short duration of most fish-canning seasons is stated as the principal reason for non-adoption of this cooker in the fish-canning industry. This explanation may be valid in the salmon-canning plants, but not in the California fish-canning industry. A tuna cannery which uses the agitating cooker has found that the cost is not greater and that processing troubles are less.

RETORT OR COOKER REQUIREMENTS

Cookers should be of such size that 30 minutes will be the maximum time required for loading any single retort. A longer loading period may affect the sufficiency of process and the quality of the product. The material used should be heavy steel plate, preferably welded rather than riveted, and capable of withstanding a pressure of 50 pounds per square inch. Construction with too light a weight of steel plate is a fault frequently encountered in fish-cannery retorts, especially where they have been manufactured by some local boiler maker.

All retorts should be well insulated with a layer of asbestos or similar material to reduce heat losses. Heat loss may be considerable in un-insulated retorts of light construction, and an appreciable saving is made in steam consumption, when the retorts and all steam pipes are insulated.

The capacity of the retort should be approximately 20 percent in excess of the expected maximum requirements. Many canneries, especially on the Gulf and Atlantic Coasts, have too few retorts, the number being just sufficient to process the daily pack, with no reserve in case of an extra–heavy peak load. For example a typical shrimp or oyster cannery is equipped with 5 retorts, when it should have 6. When possible, retorts should be equipped with full automatic time and temperature control, while recording chart thermometers should be mandatory, and equipment for cooling in the retort is recommended as an improvement in packing technique.

COOLING AND CLEANING THE PROCESSED CAN

Equipment required in cooling the canned product after processing depends on whether the cannery uses (a) air cooling, (b) water cooling, or (c) pressure cooling in the retort.

If the product is air–cooled, the crates or trays of hot cans remain on the warehouse floor until they are sufficiently cool for stacking, or labeling and casing. No effort is made to control cooling and no equipment is necessary to handle the product in this stage. The majority of fishery products canneries probably air-cool their products. The advantages of air cooling are its simplicity and cheapness. The disadvantages are that more floor space is required; and it is more difficult to control processing to prevent discoloration, loss of flavor or other physical and chemical changes.

Water cooling is more rapid than air cooling, and is necessary in packing products where a slight over-process, such as may occur in slow cooling, will injure the color and flavor, or cause excess shrinkage. Water cooling also permits labeling and casing within a short time after processing, and reduces the amount of floor space required for cooling. If water cooling is not done carefully, the cans are liable to rust and corrosion, and labels may become discolored.

Canned products may be water-cooled by sending the cans through sprays of water at considerable pressure, using an overhead conveyor system for transportation of the cans, or the trays or crates of hot cans may travel through (1) long tanks of water on a roller conveyor, or (2) the hot cans may be dropped in tanks usually not much larger than the retort. A water inlet at the bottom of the tank and an overflow pipe fitted in near the top provide a constant circulation of water.

Since most of the second type of tanks are constructed at the cannery by its mechanics, they are sometimes ineffective, due to faulty construction. The most common fault is an inadequate circulation of water, caused by the use of inflow and overflow pipes too small in size. The inflow pipe from the water system should be at least 1 inch in diameter, and the overflow pipe from 1 to 1½, or even 2 inches in diameter.

When the tank has a diameter barely large enough to admit the retort crate, the time required for cooling is increased. The diameter of the tank should be from 1¼ to 1½ times greater than that of the retort crate. A tank that is too small is inefficient in cooling and its use is a false economy. Tanks may be made of wood or metal, but metal is preferable.

Cooling in the retort under pressure usually prevents buckling of the containers when packing cans of large diameter. Buckling is caused by excess pressure within the container, which always exists in pressure processing and is caused by expansion of the solid and liquid contents and of the gases released when they are heated. If the excess internal pressure becomes too great, the can is permanently distorted or buckled. A buckled can not only is is unmerchantable because of its appearance, but may become leaky.

Buckling may occur either during processing, or when the pressure in the retort is being reduced to that of the atmosphere. Buckling during processing usually may be prevented by reducing the contents of the can or by increasing the closing temperature. Buckling when the retort is being brought down to atmospheric pressure almost always is caused by excessive rapidness in this step; by increasing suddenly the excess of pressure within the container. Such buckling may be prevented only by maintaining the proper external pressure until the internal can temperature and pressure have been reduced. Cans of small diameter may withstand considerable excess internal pressure without being distorted but the ability of cans to withstand excess internal pressure without buckling diminishes rapidly as their size increases. Products packed in cans larger than a No. 3 size, and processed under pressure, must be cooled under pressure to prevent buckling.

Pressure cooling in the retort may also be used to advantage with small diameter cans, and must be used in processing all sizes of glass containers, since the lids otherwise will blow off when the retort is brought down to atmospheric pressure. Retort pressure must also exceed the pressure within the glass container during processing, or the lids will be forced off.

Theoretically, the purpose of pressure cooling is to make the internal and external pressure on the container as nearly equal as commercially practicable, during the cooling process, in order to prevent both buckling of the ends (outward distortion) and paneling (inward collapse).

In actual practice, the retort pressure is made equal to, or slightly greater than, the pressure at which the cans were processed, during the initial stage of cooling, and is then gradually reduced as the internal pressure of the cans decreases during cooling. Two methods of pressure cooling are in use: (a) Pressure cooling by the use of steam and water and, (b) pressure cooling by the use of air and water.

Pressure cooling by the use of steam and water require the presence of a few inches of water in the bottom of the retort. When the processing is concluded, cooling water is allowed to enter under a baffle at the bottom of the retort. This must be done carefully, or the cold water will break through the hot water layer, thereby condensing the steam and suddenly creating a vacuum. Steam pressure is maintained above the water level until the retort becomes filled with water. The advantages of this method are (1) economy of installation, and (2) simplicity of operation. The disadvantages are: (1) "Spangled" cans may result if water comes in contact with the cans in the lower part of the retort during the processing; (2) the steam consumption is somewhat higher than when method (b) is used, and (3) the rate of cooling of cans at different levels of the retort is not uniform during the time the retort is being filled with water. In the top of the retort cans are still surrounded by steam, while cans in the bottom of the retort are in water.

Pressure cooling by air and water does not require the use of water in the retort during processing, but retort equipment must include a compressed air reservoir in which a minimum pressure of 50 pounds is maintained at all times. At the end of the processing period, compressed air and water in the form of a spray, are admitted to the retort. The pressure level within the retort is maintained by air pressure which replaces the steam condensed by cooling water. The advantages of this method are: (1) The rate of cooling is uniform throughout the retort; (2) the retort may be filled with water in a much shorter time and (3) low steam consumption. The single disadvantage of this method is the somewhat higher cost of the equipment.

A diagram of a vertical retort used for pressure cooling is presented in figure 11 and its operation is explained below.

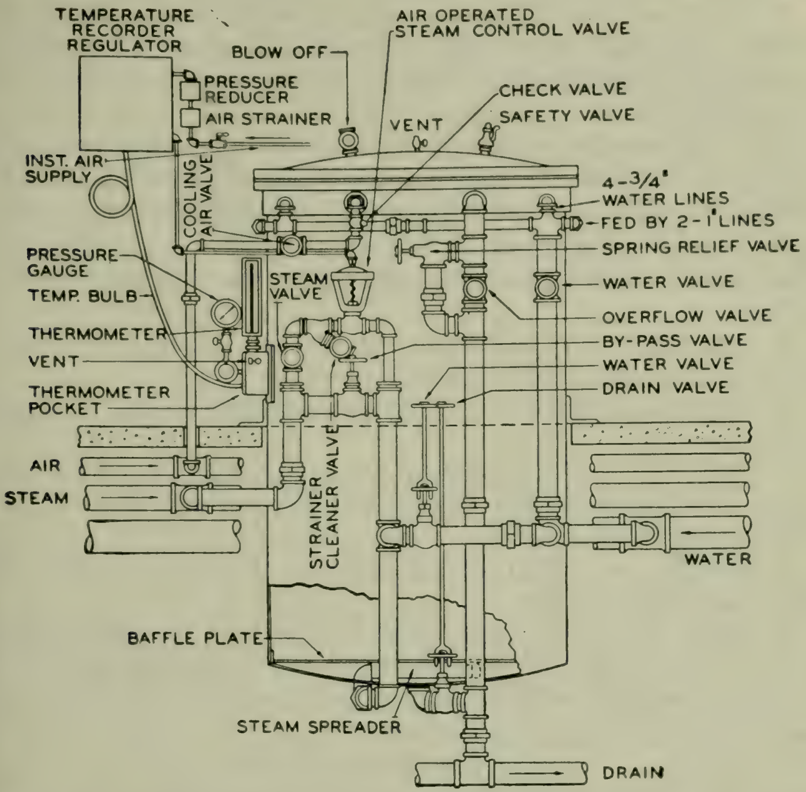


FIGURE 11.—Diagram of vertical retort equipped for pressure cooling. (Courtesy, American Can Company.)

INSTRUCTIONS FOR OPERATION[4]

I. *Steam and water method of pressure cooling.*—The procedure for pressure cooling by this method is given below. The various control steps beginning with the completion of the process are listed in chronological order for a vertical retort. The operation of a horizontal retort by this method is essentially the same.

1. Close all vents except that on the thermometer pocket.
2. Open valve (P) admitting steam into the top of the retort.
3. Close valve (S) which has admitted steam during the process.
4. Open valve (W) admitting water into the bottom of the re-

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[4] American Can Co. Pressure cooling in horizontal and vertical retorts, 7 pp. 3 plates. New Orleans Research Dept. Memo. American Can Co., Inc., New Orleans.

tort under baffle. Care must be taken not to permit the incoming water to break through the hot water layer.

5. When water level reaches the height of the thermometer pocket vent the pressure may be maintained without further loss of steam, and valve (P) is closed.

6. The pressure may increase suddenly as the retort is filled with water and if the spring relief valve (R) is not sufficient enough to control it, the overflow valve is opened enough to release the excess pressure.

II. *Compressed air and water method* (Vertical and horizontal retorts).—The control steps for this method beginning with the completion of the process are given in chronological order below.

1. Close all vents except that on the thermometer pocket of vertical retorts or the indicating petcock on the side of horizontal retorts.

2. Open valve (A) admitting air into the retort, and build up air pressure 4 lbs. over processing pressure.

3. Close steam valve (S) which has admitted steam during the process.

4. Open valve (W) admitting water through spray at the top of the retort as rapidly as possible without causing a pressure drop of more than two pounds.

5. Maintain an initial cooling pressure of 3-4 lbs. greater than the processing pressure.

6. When the water level reaches height of the thermometer pocket petcock on vertical retorts or the indicating petcock on horizontal retorts the pressure may be maintained without further use of air and valve (A) is closed.

7. The pressure may increase suddenly as the retort is filled with water and if the spring relief valve (R) is not sufficient to hold it, the overflow valve (O) is opened enough to release the excess pressure.

8. After the retort has been filled with water permit a rapid inflow of water at the top and outflow through the overflow for one to two minutes. Then slowly and simultaneously, open water valve (W) admitting water to the bottom of the retort and close valve (W) admitting water to the top spray.

After these steps have been carried out, the pressure of the cooling water in the retort is gradually reduced to correspond with the reduction of the internal pressure of the containers, according to a definite cooling schedule, which varies according to the product, can size, and processing temperatures. Detailed schedules may be obtained from the technical departments of the leading can makers or from research laboratories connected with the canning industry. Pressure is reduced in about four stages and the time required will vary from a total of approximately 10 minutes in products of rapid heat penetration, to 30 minutes where the rate of heat penetration is slow and the can dimensions of the largest size. After pressure is reduced to atmospheric level the cans must remain in the retort until the contents have cooled to an average temperature of 100° F.

Manual control, as discussed here, may be eliminated entirely, and the process made fully automatic, by equipping the retorts with additional controllers on the water line, air line, and overflow, and connecting this equipment with a time regulator. Installations of this type have been used satisfactorily for some years in plants packing seafoods. Though the expense of the equipment is greater, the elimination of error through faulty manual operation, and the reduction in labor required, more than counterbalance the added cost.

SANITATION IN CANNING

WHY SANITATION IS NEEDED

Strict sanitary measures are necessary in the canning of fishery products not only for hygienic and esthetic reasons, but also to reduce operating losses and maintain a high quality of product which can be sold at a satisfactory price. Sanitation should not be confused with superficial cleanliness, a tendency observed in certain canneries. The occasional use of a disinfectant such as calcium hypochlorite (chloride of lime) cannot serve as a substitute for the regular and thorough application of generous quantities of water or steam (Hunter, 1934).

Sanitation in canning begins with catching the raw material. Bacterial contamination and consequently decomposition is increased by the misuse of catching apparatus or by the use of types of gear by which the fish may be damaged, causing deterioration to occur before landing. As a measure to improve sanitation, if for no other reason, types of apparatus landing the catch in best condition should be used.

The holds of fishing boats or craft used to transport raw material to the cannery should be so constructed that slime, offal or other waste will not accumulate in the bilges and so that the bilges may be cleaned easily and thoroughly at frequent intervals. Hold linings of wood should be painted regularly or otherwise treated to render them non–porous. Holds, decks, bins, boxes or other equipment used in transporting should be washed down and scrubbed after each delivery of raw material, using clean unpolluted water under considerable pressure.

The use of salt water pumped up from the vicinity of a cannery dock is not desirable as it is usually heavily contaminated with spoilage organisms. The efficient application of a hypochlorite solution is an additional safeguard but cannot serve as a substitute or reduce the necessity for thorough washing.

PUBLIC HEALTH REGULATIONS AND SANITARY CODES

Bare compliance with local public health regulations is not sufficient because requirements are sometimes loosely drawn or incomplete and are not always strictly enforced. Canning research authorities have drawn up excellent sanitary codes but it is not enough to pledge adherence to such a code. Pledges must be backed by close and constant attention to every detail which may reduce contamination from the gathering of the raw material to the cleansing of containers after processing.

REFRIGERATION

Refrigeration is sometimes necessary to maintain raw material in a proper condition of sanitation. Ice should be used even on short hauls when the temperature is much higher than normal. This ice should be finely crushed or it will bruise the raw material, and used in generous quantities, at least 50 pounds of ice per 100 pounds of raw material.

RAW MATERIAL HANDLING

Raw material should be inspected carefully on arrival at the cannery and only fresh, clean and undamaged raw material should be accepted. Rough handling in unloading should not be tolerated. Raw material found unfit for use should be destroyed immediately or sent to a reduction plant.

Washing and cleaning of raw material preparatory to canning must be supervised carefully since sanitary control at this stage is one of the most important factors in reducing losses through spoilage. Offal or other debris should not be allowed to accumulate on the floor or around the cleaning equipment but should be carried off immediately. Discharge of waste by chutes or flumes into water near the cannery should not be permitted even if the tides are strong. The use of individual containers such as barrels or garbage cans in handling fish offal should also be discouraged as such containers are difficult to keep clean, are not always removed promptly from the cannery area, covers are lost or are placed on carelessly, all encouraging the breeding of flies. Wherever economically possible, cannery waste should be utilized immediately in the manufacture of by-products. In some plants, cannery waste may be discharged directly into a sewer but this presents certain difficulties especially where sewage treatment systems are in use.

If raw material is permitted to remain in cleaning, washing or blanching tanks longer than necessary the delay often results in an extremely heavy contamination with spoilage organisms. To avoid prolonged exposure and subsequent contamination material in small pieces should be carried through these operations in heavy wire mesh baskets or similar containers and tanks should be drained completely and scrubbed at short intervals throughout the day.

No attempt should be made to economize in the use of water since large quantities are required to efficiently remove blood, slime, scales, viscera and dirt, or other waste. Furthermore the use of large quantities of water reduces bacterial contamination, where the water itself is uncontaminated.

USE OF WOODEN EQUIPMENT

The National Canners Association (1939) stated in Bulletin 26-L:

> In general, the use of wood in canning equipment is hazardous, for bacteria may become seeded in the pores and once established may contaminate food materials to such an extent that spoilage may occur with a process that has been satisfactory for years. Any wooden equipment with which food materials may come in contact, such as brine and hot water tanks, conveyors, blanchers, canning tables and even such items as paddles and rollers may act as a carrier of contamination. For example, wooden tanks used for storage of hot water for general plant purposes have been responsible for contaminating a whole canning system. Wooden brine tanks, at the beginning of a day's run, have been found to supply large numbers of organisms to the product being canned. Owing to dilution their number decreases markedly during steady operation only to build up again during a shutdown. Wood, being porous, is able to retain bacteria and hold them mechanically immune from scrubbing and other cleaning processes.

Wherever possible, tanks, filling tables and other articles coming in frequent contact with the fish in canning should be made from some non-corroding metal.

PERSONAL HYGIENE

Freedom from contagious or infectious disease should be made a condition of employment for all cannery employees and no one who contracts such a disease should be permitted to return to work until public health authorities certify that reemployment will not endanger fellow employees or infect the product. Processes used in canning fishery products are believed sufficient to destroy anything less than a gross infection of disease organisms. The principal danger is infection of other employees followed by a decrease in the quality of their workmanship.

Employees should be required to observe proper habits of cleanliness. Such habits as spitting on the docks or in and about the various cannery buildings; smoking in the cannery; urinating elsewhere than in the toilets; befouling the toilets, and carelessness in throwing lunch bags, empty cans, bottles, or other waste elsewhere than in receptacles provided for the purpose, should be punished by instant discharge. All employees handling the product should be required to keep finger nails short and well-cleaned, and to wash their hands thoroughly on each absence from work.

If cotton gloves are used in handling the product they should be changed frequently throughout the day and should not again be used until after they have been thoroughly laundered. Gloves rinsed in water and then spread out to dry on a retort or in some other place in the cannery are not sanitary and serve as a possible source of increased contamination.

In some fish–canning plants the use of washable clothes, aprons and caps is advisable. Sanitary codes state that these shall be changed "frequently." This rule is sometimes misinterpreted and clothing may only be changed once a week, instead of whenever soiled, or at least daily.

CANS

While in storage, empty cans should be protected from contamination and the possible inclusion of dirt or vermin. Every precaution should be taken to keep the cans clean before use and when possible they should be washed just before going to the filling machine.

Filled cans should not be allowed to stand on filling tables or at the closing machines for periods longer than a few minutes. All filled cans should be sent to the retorts before stopping work for meals or for other reasons. Trays of material to be filled into the cans should not be allowed to stand on the filling table at such times and should be carefully screened from flies or other insects.

CLEANING EQUIPMENT

Haste in clean–up operations at the end of the day is often a source of increased contamination and lowered sanitary standards. It is not enough to flush the floor, tables and tanks hurriedly and clean up obvious debris and waste from exposed surfaces. Cleaning must be thorough and include all corners, cracks, pipes, screens or other places which might be sources of contamination. Butchering, or cleaning and filling machines should be dismantled, cleaned thoroughly and left dismantled when not in use. The National Canners Association Research Laboratory also suggests that to remove unavoidable residual contamination such equipment should be flushed with water before its next use. Each employee should be responsible for the cleanliness of the area where he or she works, and the superintendent should assign to some person the duty of inspecting all cleaning to ensure a thorough and efficient job.

HANDLING WASTE

Packers of oysters and clams often allow shells to accumulate in large heaps near the cannery for later manufacture into poultry grits or other secondary products, or distribution on oyster beds as "culch." This creates a serious nuisance, as there is an appreciable amount of decaying organic material attached to the shells, attracting clouds of flies and increasing the possibility of micro–organic contamination. Rubbish of any kind should not be allowed to accumulate around a plant. Old fish boxes or defective and spoiled containers of the cannery product may possibly be salvaged, saving comparatively small amounts in operating costs, but the danger to the product overbalances any possible gain.

Reduction plants manufacturing whole fish, or cuttings from fish, into oil and meal should be located at some distance from the cannery. No matter how carefully these plants are operated their proximity to canning operations increases problems of sanitation. Press liquors, tank residues, and other effluents from such plants should not be discharged into water near the cannery.

OPERATIONS INVOLVED IN CANNING

The canning of fishery products may be divided into a number of definite steps applying equally well to all types, although details of methods and processes vary with the individual product. To discuss points of importance in certain operations common to all canning procedures in the description of individual products would cause duplication, or the information would be presented in disjointed fragments whereby most of its value would be lost. Therefore, a general discussion of the steps in canning follows.

SECURING THE RAW MATERIAL

The quality of the product and the price range at which it is to be sold usually determines the choice of fishing gear and the method of fishing. For instance, tonging could hardly be used extensively in obtaining oysters for canning. It would be too slow for mass production or would require the efforts of so many men that production costs would be raised so that canned oysters could not be packed at a price the consumer could afford. Since the oyster tonger can operate only in the shallower waters, this method would also limit the catch by restricting the fishing area.

The pack of canned shrimp has been increased and the price reduced largely because it has been found possible to procure a larger supply at less cost by adopting nets of the otter–trawl type, instead of the haul seine formerly used. The trawl nets have been found to be more efficient since they can be operated at depths and in areas previously unfished, and can also be operated more cheaply.

Raw material taken from the same area by different types of gear may differ in quality when landed at the cannery. Fish taken by gill nets are "drowned" and always receive more handling than fish taken by other types of gear such as the trap, which means that decomposition is accelerated and the length of time the raw material will remain in good condition is reduced. Therefore gill nets are suitable for use only where the fishing grounds are in close proximity to the cannery and transportation facilities permit frequent pick-ups from the fishermen and prompt delivery at the cannery.

In canning salmon, the trap or pound net is considered the best type of gear since this apparatus is the most efficient where its use is practicable or permissible. It is also easier to control the flow of raw material which is usually of better quality when it reaches the plant because the fish may be held alive until needed. The fish are not handled so much and fewer water–marked salmon, fish closely approaching the spawning stage, are taken.

As a rule, the method which supplies the largest amount of good–quality raw material most cheaply should decide the type of gear to be used. The most efficient apparatus cannot always be adopted; sometimes it is too efficient and causes depletion of the fishing grounds and therefore may be prohibited by law or regulation. Finally, due to political considerations, the use of certain types of gear has been forbidden in some States.

In some areas the cannery owns the fishing craft, and the men who operate the gear are paid a fixed monthly or daily wage. On other fishing grounds the cannery supplies the equipment, contracting to purchase the catch on a poundage basis. In still other instances the fishermen may own boats and gear, selling the catch to the cannery operator according to a scale of prices previously arranged by contract. In some cases the catch may be sold on the open market to the highest bidder.

Open–market purchase is not practicable for the majority of packers and is only economical when the fresh market is in a depressed condition. The packer should have a steady supply of raw material and should be able to estimate his packing costs accurately, especially if the pack has been sold under contract previous to manufacture as is often the case. As a rule the packer cannot risk depending on fluctuating market prices or on securing a steady and adequate supply of raw material on the open market.

It is also to the advantage of the fisherman, equally with the packer, to have a steady market for his catch at a definite price. Costs of operation, especially of boats and gear, are high. This is one reason why many fishermen do not operate their own gear. The fisherman may "catch the top of the market," but too often he finds the price that he obtains at open sale leaves him no return for his efforts.

Canners of fishery products, especially those operating on a small scale, often find it more desirable to lease rather than to purchase fishing craft and apparatus at least for the first few seasons of operation. Where the canning season is short and it is difficult if not impossible to turn boat and outfit to other fisheries for the balance of the year the fisherman probably should not attempt to operate his own outfit.

TRANSPORTING AND RECEIVING

All raw material in any one lot should be equally fresh on receipt from the fisherman. Sometimes when fishing is poor the fisherman is apt to delay delivery, hoping to secure a better boat load. Unless it is possible to enforce regular deliveries there is considerable variation in the freshness of the material.

Since fishery products spoil quickly, the time elapsing between the time of catch and that of receipt at the cannery should be as short as possible. It is not possible to set a certain specified time for this period; it is affected by many variables such as temperature and humidity. For example, in Alaska, salmon will usually remain in good condition for canning for 48 hours, but during certain seasons some fish or portions thereof will show an appreciable degree of staleness after 12 hours.

If fish or crustaceans are piled to any great depth in the hold of a vessel, pressure will cause overheating which rapidly advances the rate of deterioration. Heavy pressure also contributes to softening the texture of the lowest layer, mechanically tearing and bruising the flesh, and increasing contamination due to the greater amount of slime dripping down from the excessive upper layers.

Raw material is sometimes transported in boxes holding about 500 pounds, net weight. These boxes may be piled to any depth since the pressure is divided and no individual fish is subjected to a heavier pressure than the weight of the other fish in that particular box. The holds may also be divided into pens, which are capable of further subdivision by removable floors at different levels.

The raw material should be handled as little as possible and any carelessness in handling should be penalized. "Forking" or "peughing" should be forbidden absolutely or restricted only to the head of the fish. Peugh holes in the body not only provide an easy entrance for spoilage organisms, thus hastening deterioration, but also cause dark discolored streaks in the flesh which are often visible in the canned product. Trampling upon, throwing or bruising the cargo not only lowers the quality of the raw material but often makes it unusable in products of any grade.

GRADING

The raw material should be graded and sorted into different bins on arrival at the packing plant. A standardized system of grading has not been developed in the preparation of any canned fishery product but a number of methods are in use varying according to locality, experience of the packer and the product. In general, grading is dependent on freshness, size and species of fish and color of the flesh. Careful grading is essential to the preparation of a high quality canned product.

The condition of the fish on arrival may be determined by a number of factors. Odor is important in judging freshness, but the sense of smell varies with the individual. While some are hyper–sensitive, others cannot recognize the difference between fresh and slightly stale fish. The ability to judge by odor also seems to vary with the health of the individual and is affected by smoking and drinking.

A rapid determination of freshness may best be made by judging firmness, appearance of the gills, eyes, and the flesh of the belly cavity near the backbone. The flesh of fresh fish is firm and resilient, so that when pressed with a thumb in the thick portion of the back, the impression will gradually disappear when the thumb is removed. If fish are fresh the gills will be clear pink to deep red in color, firm, free from slime, and with an odor which may best be described as a "salt water odor," rather agreeable and free from any suggestion of taint. The eyes of fresh fish are bright, clear and protuberant. The flesh near the belly cavity around the backbone, should be free from discoloration and may be stripped away from the backbone only with difficulty, leaving many shreds clinging to the bone.

When deterioration sets in, the flesh becomes soft and flabby in texture, and the impression will remain if a thumb or finger is pressed into the thick back flesh. The gills acquire a faded brown color, which may become gray or grayish–green in a rotten fish, and are covered with a thick lumpy slime. The odor of the gills is rank and unpleasant if the fish is stale, changing to a characteristic tainted or putrid odor as decomposition continues. The eyes are dull, opaque, sunken and often bloodshot. The flesh around the backbone shows a dull red discoloration and may be stripped away easily and cleanly.

In some packs such as shrimp and sardines, size is an important factor in grading. Carelessness in sorting to size will result in poor appearance and may cause difficulties in filling.

A catch may include several species. A single delivery of salmon may include five, some of which are more highly regarded than others though all are about equal in food value. If carelessly graded according to variety the contents of a can may be composed of pieces from two species of noticeably different appearance.

The color of the flesh is of importance in the production of several fishery products. In the Columbia River chinook salmon there is variation of color within the species and fish of several shades may be taken in the same delivery. The deeper shades of color are considered more desirable, so separation according to shade is necessary in the production of a "fancy" pack. Variation in color also occurs in some species of clams but in this instance the lighter color is preferred for "high quality" packs, especially of minced clams. Mixing of grades operates principally to the loss of the packer since such products are sold at the price of the lower grade.

DRESSING AND WASHING

Dressing and washing is the first step in the actual process of manufacturing the canned product and consists of removing viscera and other waste material, and of freeing the raw material from blood, slime or dirt by the use of generous quantities of water. Dressing or cleaning must be carefully and closely supervised at all times in order to prevent needless loss of edible material which is sometimes sufficient to destroy the margin of profit. Careless cleaning may also result in the inclusion of waste in the canned product. This is considered as adulteration by the U.S. Food and Drug Administration.

Washing may be of three general types, soaking or tank washing, washing by agitation, and spray washing. Tank washing may act as a source of contamination rather than a means of cleansing unless the water is changed frequently. Soaking or tank washing is effective in removing blood but softens texture if the fish are left too long in the tank, unless a salt brine is used. Oversoaking in salt may toughen the texture or make the canned product unpalatable.

Agitation increases the efficiency of washing. The earliest development of this type of washer in fisheries is the wooden flume conveyor in which the fish are carried from the cleaning and trimming section to the pre-cooking or preparation stage by a current of rapidly running water. Another simple type of agitating washer is the tank equipped with a propeller. Unless the propeller is guarded by a heavily screened cage or is geared to move slowly it may bruise the fish. Compressed air is sometimes used to agitate water as in the oyster shucking "blower" which is probably the most efficient type of agitating washer.

The drum or squirrel–cage washer is also used widely in the canning of fishery products. It consists of a drum of heavy small mesh wire screen with a central axle and equipped with longitudinal baffles of angle iron at intervals around the inner circumference. The drum revolves in a tank of water. This type is used in washing herring, Maine sardines and shrimp. Comparatively few fish are bruised, it requires little water and also acts as a scaler.

Washing fish mechanically by means of strong jets or sprays of water has increased in fish canning establishments during the past few years, and should be used even more extensively being more efficient and economical. Spray washing methods depend on pressure of water rather than volume. A combination of a spray wash with the revolving drum has been found satisfactory in washing some types of fish which must also be scaled.

PREPARATION FOR THE CAN

Some articles such as salmon and shad are simply cut into container–length pieces after washing and undergo no other preparatory treatment. Other packs, such as tuna and sardines, undergo several additional steps.

Close control of precooking, mixing, grinding and other preparatory steps is essential. For example, in steaming oysters to open the shells an excess shrinkage of several ounces in the bushel occurs if either the time or temperature exceed the normal requirements. This loss can and should be avoided.

Preparation should be continuous with the remaining steps in canning and delays should be avoided as far as possible. In some canneries material is prepared before it is required and held for several hours in order that the plant may go into full operation in the minimum length of time. In warm weather a very brief delay is sufficient for spoilage to set in and an appreciable amount of deterioration may occur which is not visible to the naked eye.

FILLING

Filling may be accomplished either by hand or by machine. Filling machines have been greatly improved in recent years but are not yet adapted for use with odd sized containers or products requiring careful handling. The principle of the filling machine is to deliver a certain volume rather than a definite weight of material. There is, however, little variation in the weight filled into individual containers. The principal objection to machine filling is that it is not always done as neatly as is desirable; for instance, salmon may occasionally be cross-packed and will not have the appearance of a smooth cylinder when removed from the container. When good workmanship in packing is desired, hand filling should be used, but it is slower and more costly.

In filling, a headspace of about ⅛ to $\frac{3}{16}$ inch should be allowed in the top of the can in order that a proper vacuum may be obtained. The tendency is to over–fill rather than under–fill a container. Canned fishery products usually weigh somewhat more than the amount stated on the label as the packer does not wish to be penalized for packing an under–weight product. Studies indicate that while the excess weight per container given away by the packer may be only an ounce or even less, the total amount lost in a season's production is considerable (Clark, Clough, and Shostrom, 1923; Sieverling, 1937). Careful control of filling will reduce this source of loss. Accurate scales or weighing machines are an economy in filling.

Filling should be carefully supervised for other reasons. Foreign objects may get into the containers at this time, through carelessness or deliberate sabotage. A nail or other fragment of metal may have been left in a can previous to filling; a portion of a cotton glove may be drawn into a can during the filling process or trays of filled cans may be left unscreened and exposed, with the result that a fly may be included in the product. These objects have all been found in containers. Even where damages are not awarded, legal costs are expensive and each instance means a loss of sales through newspaper publicity. Cans should be absolutely clean when they reach the filler while the filling area should be screened and protected against flies or similar sources of contamination.

EXHAUST OR VACUUM AND SEALING

Sufficient exhaust or vacuum may be obtained by (1) filling a hot precooked product into the container and sealing immediately, (2) by heating after the product has been packed into the container and (3) by mechanical means. The choice of method will depend on the product, space available in the cannery and scale of production.

Products such as soups and chowders are precooked, filled into the container while hot and sealed immediately. Others, such as fish roe, are "exhausted" by passing the container through a steam heated exhaust box. A mechanical apparatus (vacuum–sealing machine) which combines the functions of exhausting and sealing is used in most salmon canneries and is especially suitable when space is at a premium as on floating canneries. Vacuum–sealing machines have not yet proved to be economical for small scale operation as in the packing of specialty articles but they are being improved, and their use may soon extend even to small scale operations. The older system of using a heat exhaust to obtain a partial vacuum, sealing the cans in a second operation, has not been entirely displaced, but is apparently fast becoming obsolete.

"PROCESSING", "COOKING" OR "STERILIZING"

A few years ago little skill was required of the man responsible for processing and great latitude was allowed in the operation of the equipment. The processing equipment was comparatively simple and errors due both to faulty equipment and to the human factor were more frequent than they are now. Fish products were too often regarded as "fool–proof." Accurate and detailed processing records were not kept in many instances. As a result the quality of the pack was not uniform and spoilage occurred directly traceable to preventable faulty processing.

It is difficult, if not impossible to eliminate faulty processing and insure against human error if sterilizing equipment is operated manually, with a pressure gauge and indicating mercury thermometer too often untested for accuracy as the only control devices. Retorts should be fitted with at least the following equipment: (1) An automatic control for regulating temperatures. (2) An indicating mercury thermometer of a range from 170 to 270° F., with scale divisions not greater than 2° F. (3) A recording thermometer of a range from 170 to 270° F., with scale divisions not greater than 2° F. (4) A pressure gauge of a range from 0 to 30 pounds with scale divisions not greater than 1 pound. (5) A blow–off vent of at least ¾ inch inside diameter in the top of the retort. (6) Bleeders not less than ⅛ inch diameter. (7) Adequately perforated steam inlet pipe running through the length of the retort. (8) A drainage valve.[5]

Indicating mercury and recording chart thermometers must be installed either within a fitting attached to the shell of the retort, or within the door or shell. If the thermometer is installed within a fitting, the fitting should communicate with the chamber of the retort through an opening at least 1 inch diameter and should be equipped with a bleeder at least ⅛ inch, inside diameter. If the thermometer is installed within the door or shell of the retort, the bulb must project at least two thirds of its length into the principal chamber. The pressure gauge is connected to the chamber of the retort by a short gooseneck tube. The gauge must not be more than 4 inches higher than the gooseneck. The bleeders should be spaced not over 1 foot from each end of the retort and not more than 8 feet apart.

Processing times listed in canning literature do not include the entire period from the time the product is placed in the retort until it is removed but only the length of time after the retort has reached the required temperature and until steam is shut off. The time required for bringing the retort up to processing temperature and for reducing pressure to atmospheric level are in addition to the processing period and it is important that sufficient time should be allowed for each of these steps. If properly processed the product should be neither overcooked nor should it have an "understerilized" flavor, while the texture should be reasonably firm yet not stringy or woody.

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[5] 1936. Proposed regulations for inspection of canned salmon under section 10-A of the federal food and drug act. Food and Drug Administration, U. S. Dept. of Agric., Washington.

COOLING AND WASHING

Since a sudden release of pressure after processing causes severe strains on tin containers, which may result in leakage and spoilage, the pressure should be reduced slowly and gradually. From 5 to 10 minutes should be allowed to bring the retort pressure to atmospheric level and before opening the retort doors. Water cooling in the retort will also cause buckling and distortion, especially of larger sized containers, unless the water is admitted from below. The water should be admitted slowly at first and under air pressure sufficient to maintain a pressure in the retort equal to the steam pressure required for processing.

Most canneries packing fishery products still cool and clean the cans after leaving the retort. The pack should be cooled as rapidly as possible. If cooling is unduly prolonged, especially by stacking cans very shortly after removal from the retort the product will be darkened in color and overcooked in flavor. The necessity for cleaning the cans after processing has been reduced but not entirely eliminated by the general use of can-washing devices previous to processing.

CODING

It should be possible to identify any container as to species, grade, date and place of pack and in some instances the origin of the raw material, or method of catch. This may be accomplished by "coding" or marking by a system of numerals, letters or special symbols, using a simple, carefully worked out system with a minimum of characters. In canning fishery products the codes are marked on the containers by stamping the cover with a die usually operated as an attachment of the closing machine.

As far as possible code lots should be segregated in the warehouse both before and after casing. The cases should also bear the code mark, placed so that it may be readily observed in handling the product. Some packers regard coding merely as a means of avoiding seizure or condemnation of large parcels made up of several code lots when inferiority or spoilage may be confined to a minor fraction. However, the most important function of coding is to enable the packer and distributor to better determine the grade of the product, and to improve the quality by correcting faults in workmanship and packing.

LACQUERING

For a great many years nearly all cans of fishery products were coated with an asphalt–base brown lacquer as a rust preventative. Cobb (1919) stated that this practice originated through demands of English buyers who constituted the principal market for canned fishery products in the earlier days of the industry. Little attention was paid to conditions of storage at that time. Ship holds were damp and on long voyages there was much variation in temperature and humidity so that cans were often heavily rusted on arrival at destination. Only a minor portion of the pack is lacquered at present, usually for special orders, since it has been found that a well labeled can with enameled ends, has sufficient protection against rusting, under proper conditions of storage and shipment.

WAREHOUSING

Changes in buying methods during recent years have increased the importance to the packer of proper warehousing. The tendency of the distributor and retail trader is to buy for immediate needs only, forcing the packer to warehouse a greater portion of his pack over a longer period of time. The external appearance of the containers deteriorates unless the pack is well housed. Many consumers will not buy cans with stained or rust spotted can surface or label, therefore, a bright attractive appearance of label and can is an important factor in the sale of the product.

The prime essentials for a warehouse are that construction must be of a strength calculated to withstand strains in excess of any loads it may be expected to bear; that it be dry, well lighted and reasonably cool. Canned fishery products will resist a fair degree of heat or cold for short periods, without serious injury, but continued heat or repeated alternate freezing and thawing are injurious to quality. The product becomes flabby in texture and loses its flavor. Chemical changes double in activity with each increase of 18° F. in temperature. Storage in a warm moist place promotes rapid deterioration.

Canned fishery products deteriorate very slowly if well stored. Samples of canned fish ranging from 5 to 12 years old have been examined and were found to be still of satisfactory quality. Most canned fishery products require a few months storage before distribution, as salt and other ingredients are absorbed gradually and therefore the flavor may be uneven and judged unfairly if the goods are consumed shortly after packing. The "ripening" of sardines is an illustration in point.

However the packer cannot afford to hold his pack in storage over a long period. Goods in storage represent unproductive capital on which interest must be paid, and warehouse charges must be added to the cost of the product. Packs held longer than a few months are often subject to several forms of taxation which might otherwise be avoided.

LABELING

The product may be labeled and packed in cases for shipment immediately on cooling or it may be stacked for labeling and casing later. A portion of the pack may be cased unlabeled for the buyer using his own label. The packer should guard against labeling and casing too soon after packing because labels do not adhere well if applied while containers are still slightly warm and fiber cases insulate the cans unduly prolonging the cooling process.

Hand labeling, except in the case of oval cans and other odd shaped containers has been largely replaced by automatic machines of light construction and simple operation which may be easily transferred from one point to another in the warehouse as needed. A workman places the cans on a conveyor and they roll through the machine by gravity. The cans travel over small rollers which apply a small amount of adhesive, either glue, a casein preparation, dextrine mucilage or other type of label paste. They then roll across a stack of labels, one of which is picked up by the adhesive on the can and is fixed in place automatically by the machine. Finally, adhesive is applied automatically to the end of the label which is then sealed to the can (Cruess, 1938).

The value of a well-designed label and a well known brand is undoubtedly very great. The design should be simple and clear, the brand name easily remembered and pronounced, for customers will not remember or call for a name of difficult pronunciation. Consumers cannot read the label and depend on the picture in a number of markets in the South, or in foreign sections of cities in the United States and in certain export markets. If the picture is misconstrued the sale of the product may be adversely affected. Canned fishery products have been refused in some markets because they showed a fish with the tail not curved upward and the retail buyers therefore claimed that the fish was not fresh when packed. In one instance a good sized shipment of salmon sent to the oriental market had to be relabeled because it bore a picture which led the buyers to believe that the cans contained cat meat.

Brand names are protected by law under the "Trade Mark" Act. For a small fee the records of the U.S. Patent Office at Washington, D. C., may be searched to determine if a name or brand is registered. Attempts have been made to imitate distinctive designs in order to promote an unknown brand. In other instances the design has led the customer to believe that he was purchasing one species when the container held an entirely different variety. Such labels do the packer more harm than good since the products acquire the reputation of being second–grade imitations.

The label must comply with the regulations of the U.S. Food and Drug Administration. It must bear the net weight of the contents, conspicuously placed, the name of the article, the packers' or distributors' name and address, and the grade. The use of labels which lead the buyer to believe that the species is superior to that contained, or are otherwise deceptive as to quality, is considered as misbranding, when grade is determined by species. The Food and Drug Administration does not approve labels but will advise packers as to labeling regulations with which they must comply. There is one exception to this rule; it must approve all labels under which inspected shrimp are packed.

A digest of the procedures for canning fishery products of various kinds is presented in table 9.

TABLE 9.—*Canning of fishery products, procedures and packing data, condensed*

Product	Season	Cleaning loss	Pre-treatment	Blanch or precook	Total loss	Exhaust	Closing temperature
		Percent			*Percent*		*Deg. F.*
Salmon:							
Chinook	Varies from year to year according to necessity for conservation of supply. See fishery regulations for Alaska, British Columbia, Washington and Oregon. In general, June through September.	30	Wash and cut in container length pieces.	None	30	Vac. seal	Room temp. (60-70)
Red		33	do	do	33	do	do
Coho		33	do	do	33	do	do
Pink		35	do	do	35	do	do
Chum		33	do	do	33	do	do
Sardines:							
California	Northern dist. Aug. 1 to Feb. 15. Southern dist. Nov. 1 to Mar. 30.	No data	Brine 45 to 90 min.	1. Raw pack	50	Vac. seal	70
				2. Fry—large, 7 min.; small, 4 to 6 min.		12 to 15 min. ex	150
				3. Steam exhaust, 25 to 40 min.		Sealed hot	150
				4. Steam exhaust, 20 to 25 min., then through super-heated steam, 240 to 260° F.		do	150
				5. Oven cook, steam and gas 20 to 40 min.		do	150
				6. Oven cook, gas, 45 min. "Ullman" Cooker.		do	150
Maine	Apr. 1 to Dec. 1, most of canning during period July 1 to Aug. 1.	15 (small fish)	Salted in boat, 280 lb. to hogshead (1200 lb.)	Steam 18 to 20 min., 212-220° F.	35 to 41 (small fish), 55 to 60 (large fish).	Cold fill, no exhaust.	65
Mackerel:							
Boston	July 15 to Oct. 1	30	Brined 1 hour in 100° brine. (salt mackerel—12 hours in 100° brine).	Raw	50	15 min. at 210° F.	160
California	July 1 to Oct. 1	30	Brine 1 hour in 80 to 90° brine.	Raw	60	20 to 45 min. at 210° F.	180
Tuna:†							
Albacore	July 1 to Aug. 1 (Calif.) Aug. 1 to Oct. 1. (Oregon)	No data	Clean and wash	10 to 14 lb. 3-3½ hrs. 216-220° F. 18 to 40 lb. 4-4½ do	60 to 64	3 min. 210° F. (some packs vac. seal).	70

Bluefin	June 15 to Nov. 30	do	do	8 to 18 lb. 2 do 18 to 50 lb. 3 do 50 to 60 lb. 4 do 60 to 200 lb. 5-9 do	60 to 64		
Yellowfin	Jan. to Dec. 31 (generally more abundant in summer months).	do	do	8 to 18 lb. 2 do 18 to 50 lb. 3 do 50 to 60 lb. 4 do 60 to 200 lb. 5-9 do	60 to 64		
Striped	Aug. 15 to Nov. 30	do	do	5 to 12 lb. 2-2½ do	60 to 64		
Alewife or river herring.	Apr. 1 to May 15.	30	Brined 8 to 12 hours 100° brine.	None	30 to 35	3 min. 210° F. also filled with hot brine or water.	100 (approx.)
Fish flakes (haddock)	Apr. 15 to May 15 or at other times depending on fresh fish market.	40	Brined 10 to 14 hours 100° brine.	Steam 30 min., 240° F	70	Hot fill	150
Finnan haddie	Nov. 1 to Feb. 15	40	Brined 20 to 40 hours 100° brine then smoked 10 to 14 hours.	Fillets steam 15 min., 240° F. (whole fish 30 min.)	70	Hot fill	150
Shad	Calif Apr. 1 to May 15. Columbia River May 1 to July 1.	25	Wash, cut in container length pieces	Raw fill	35	Vacuum seal	60
Clams:							
Razor	Apr. 1 to May 31	65	Wash	Steam	65	Vacuum sea and hot fill.	150
Soft	Oct. 15 to Jan. 1 and Mar. 15 to Apr. 15.	65	Wash	Steam 20 min. 212° F., 15 min. 228° F	75	Hot fill	150
Oysters:							
Atlantic or Gulf	Jan. 1 to May 1	75	Wash	Steam 5 to 8 min. 245° F	93	Hot fill	150
Pacific	Nov. 15 to May 1		Wash	Steam 3.5 to 4 min. 240° F	80	Hot fill	160
Crab, Dungeness	Apr. 1 to Nov. 1 (Alaska—closed season during this time) Jan. 1 to Jan. 1 (Ore. Wash.)	73	Shelled alive, washed	Boiled 20 min	75	Vacuum seal	80
King (Japanese)	May 1 to Aug. 1	No data	Shelled alive, washed	Boiled 15 to 20 min. 25° brine	No data	Heat exhaust 7 to 10 min. 210° F.	165
Shrimp	Apr. 15 to June 30. and Aug. 15 to Mar. 15.	55	Brine soak 30 min. 50°	Wet pack 5 to 7 min Dry pack 7 to 12 min	75	Hot fill Vacuum seal	150 85
Clam chowder	Oct. 15 to Jan. 1 and Mar. 15 to Apr. 15.	75	Solid ingredients diced	Potato 2 to 3 min	75	Hot fill	180
Fish chowder	Apr. 15 to May 15	40 fish, 20 potato	Fish brined 10 to 12 hours 100° brine, potato peeled, washed, diced.	Potato 2 to 3 min., fish, steam 30 min. at 240° F.	70	Hot fill	160

† The season given applies only to California. Tuna of the various species are found on some part of fishing grounds throughout the year.

TABLE 9.—*Canning of fishery products, procedures and packing data, condensed*—Continued.

Product	Season	Cleaning loss	Pre-treatment	Blanch or precook	Total loss	Exhaust	Closing temperature
		Percent			*Percent*		*Deg. F.*
Fish cakes	Aug. 15 to Jan. 15	20 potato	Wash and peel potato. Soak salt cod 10 hours.	200 lb. potato, 100 lb. cod. Boil 30 min. (212° F.)	20	Hot fill	150
Fish roe:							
Alewife (river herring).	Apr. 1 to May 15	5	Rinse	Raw fill	5	Heat exhaust 3 min. 209° F. and hot fill brine.	80
"Deep sea" (Cod & haddock).	Dec. 15 to Apr. 15	None	Ground and mixed with brine.	None	None	15 min. 210° F	180
Shad	California Apr. 1 to May 15.	10	Wash, skin and slime	Raw fill	10	8 min. 210° F.	150
	Columbia River May 1 to July 1.					Some use no exhaust	60

Part 2.

Product	Brine or sauce	Fill*		Process		Yield	Remarks
		Weight	Can size	Time	Temperature		
		Ounces		*Minutes*	*Deg. F.*		
Salmon:							
Chinook	¼ oz. salt added to each can. No brine.	16.6	No. 1 tall	90	240 to 245	1 to 5 fish per case	Col. River chinook only part of pack graded for quality and is mostly hand packed.
		16.2	No. 1 flat	do	do		
		8.0	No. ½ flat	80	do		
Red	do	3.9	No. ¼ flat	70	do	12 to 13 fish per case	This species in demand because of deep red color and excellent flavor. Use of lighter colored species has given rise to rumors that some fish are dyed and sold as salmon which is entirely false. It is not permitted by law and technical difficulties of such a process are practically insurmountable.
		16.0	No. 1 oval	90	do		
		7.9	No. ½ oval	80	do		
		3.9	No. ¼ oval	70	do		
		64	(602 x 403)	195	242		
Coho	do					9 to 10 fish per case	Is not very abundant. Forms only 7 percent world's pack canned salmon. More important in fresh, frozen and smoked fish trade.
Pink	do					17 fish per case	Smallest and most numerous of salmon. Forms 41 percent world's pack.

Chum	do					9 to 10 fish per case	Has less color in flesh and lower oil content than other species so is not as popular. Sells at lower price than other species salmon but has very high food value and can be made into palatable and nutritious dishes.
Sardines:							
California	2 oz. tomato or mustard sauce to each 1 lb. oval — 1 oz. to each ½ lb. oval or 8 oz. rect.	16	No. 1 tall	75	240	Average of 13 cases of sardines per ton of fish required by Ca'if. law. Fish in good canning cond. about 20 cases to ton.	Packing of natura and smoked fillets becoming important feature of pack.
		16	No. 1 oval	65	240		
		9	½ rect.	50	240		
		8	½ oval				
Maine	Cottonseed oil	3½	(quarter oil)	45	240	20 cases per hogshead (large fish); 30 cases per hogshead (small fish).	Maine law requires; use of winterpressed cottonseed oil 4 lb. per case (100 quarter); minimum of 4 fish per can (keyless), 5 (keyopening).
		11	(¾ mustard)	60	240		
Mackerel:							
Boston	3 percent	14	1 lb. oval	75	240	66 percent	Declared net weight on 1 lb. ovals 12 oz. but fill is always heavier. Mackerel must be firm and not over 24 hrs. old.
		14	1 lb. tall				
		16	No. 2 short				
California	3 percent	17⅝	No. 1 tall (301 x 411)	9	240 or 250	No data	Some mackerel packed raw pack without brining, ¼ oz. salt added to can. Not recommended by canning technologists who urge brining be employed.
				75			
		17	No. 1 meat (301 x 407)	75	250		
		11½	No. 1 standard	75	240 or 250		
			(211 x 400)	60			
Tuna:†							
Albacore	oil and salt	9⅛	8 oz (211 x 304)	75	250		Small amounts of tuna packed in glass tumblers, aluminum cans. Number of specialty tuna packs of which "tonno" is probably most important. Other specialty packs "ventresca," creamed tuna, garlic flavored tuna. Bonito also packed tuna style but may not be labeled as tuna yellowtail packed tuna style, but may not be labeled tuna. Some canned tuna imported into U. S. from Europe packed in salt brine without oil must be labeled "Packed without oil and in salt solution."
	oil ¾ oz.; salt 1/14 oz.	3½	No. ¼ tuna	65	240	76 cases; 48/¼s per ton	
	oil 1½ oz.; salt 1/7–3/14 oz.	5½–5¾	No. ½ tuna	75	240	47 cases; 48/½s	
Bluefin	oil 2; salt 9/14	11–11½	No. 1 tuna	95	240	23 cases; 48/1s	
Yellowfin	oil 9; salt 6/7	46	4 lb. tuna	230	240		
Striped							
Alewife or river herring.	3 percent	16	No. 1 tall	50	244	No data	Labeleed "fresh river herring" but is of canned salt fish style. Fish wrapped individually in parchment paper and packed in No. 2 tall cans.
		26	No. 2 tall	60	250		

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*The fill given is actual weight filled into container and should not be considered a recommendation for declared weights to be used on the label of the container.

†The season given applies only to California. Tuna of the various species are found on some part of fishing grounds throughout the year.

TABLE 9.—*Canning of fishery products, procedures and packing data, condensed*—Continued.

Product	Brine or sauce	Fill*		Process		Yield	Remarks
		Weight	Can size	Time	Temperature		
		Ounces		*Minutes*	*Deg. F.*		
Fish flakes (haddock)	None	7¼	(211 x 300)	55	240	66 cans per 100 lbs. (211 x 300) size; 40 cans (307 x 208) size per 100 lb.	Fillets sometimes used instead of whole fish. Cod may be mixed with haddock 1 to 3, but is not often packed alone because of its soft texture.
		12	(307 x 208)	75	240		
Finnan haddie	None	4	(211 x 109)	55	240	About same as fish flakes not definitely determined.	Also packed in "nappy" glass tumblers. Imports from England in 1 lb. oval cans.
		12	(307 x 208)	75	240		
		16	(300 x 307)	75	240		
Shad	½ oz. salt	16½	No. 1 tall	90	240	75 lb. round—fish per case 48/1s.	Pack resembles salmon but flesh is rather dark and soft. Some kippered shad also canned.
Clams:							
Razor	Clam juice	5¼	No. ½	45	220	1 bu. clams = 40 No. ½ flat cans; = 20 No. 1 tall.	Sold mostly as "minced sea clams."
		7½	No. 1 picnic	45	220		
		12½	No. 2	60	220		
Soft	3 percent	6	No. 1 picnic	20	240	48 No. 1 picnic cans per bu.	Darkening is principal difficulty in canning. If this occurs blanch in 1.5 percent citric acid and add 0.5 percent citric acid to pack.
		10	No. 1 tall	20	240		
		11	No. 300	20	240		
		12	No. 2	25	240		
Oysters:							
Atlantic or Gulf	4°	3	(211 x 300)	8	250	20 to 25 No. 1 picnic (211 x 400) cans per bbl.	1 bbl. = 3 bu. in Miss.; 1 bbl. = 4 bu. in La.; Miss. bu. = 2826 cu. in.; La. bu. = 2150 cu. in.; Std. U. S. bu. = 2150 cu. in. 9/0 loss = shell, mud, oyster juice (nectar).
		4	(211 x 304)	do	do		
		5	(211 x 400)	9	250		
		8	(307 x 400)	10	250		
		10	(307 x 409)	do	do		
Pacific	3 percent	7 to 9	No. 1 picnic (211 x 400)	29	240		Pacific oysters filled by count as well as weight. Certain number oysters must go into can for each grade size. Count per No. 1 tall can usually 6 to 7 if oysters are large, 8 to 14 if grade is medium, and 15 to 20 if grade is small.
		10 to 13	No. 1 tall	35	240		
		14 to 16	No. 2	42	240		
Crab (Dungeness)	4°	6½	(307 x 202½)	70	228	20 lb. meat or 4 doz. crabs to case 48/½s.	Dry salt may be used instead of brine. Speedy operation without delay, esp. important in this pack.
		13	(401 x 211)	80	228		
		17	(307 x 408)	80	228		
King (Japanese)	See remarks	3½	(211 x 109)	80	220	No data	2 oz. weak buffer sol. of organic acid (lactic or citric) added when discoloration may occur.
		6½	(307 x 202½)	90	220		
		13	(401 x 211)	80	228		

Shrimp	4°	5⅜	No. 1 picnic and squat.	10	250	190 No. 1 picnic cans per bbl. (210 lb.).	Processes for dry pack increase as liner type changes from 3 pc. to 1 pc.
		9¾	No. 1½	12	250		
		5⅛	No. 1 picnic and squat.	70 to 85	240		
		9¼	No. 1½	75 to 90	240		
Clam chowder	Hot soup added	4 solids 6 soup	No. 1 picnic	60	240	550 No. 1 picnic to 168 lb. solid ingredients.	Down East clam chowder similar to Manhattan, except D.E. has whole clams, no tomatoes and flour instead of cracker meal.
		7.5 clam 7.5 potato 11 soup	No. 3	85	240		
Fish chowder	Hot soup added	2 fish 2 potato 6 soup	No. 1 picnic	60	240	550 No. 1 picnic to 168 lb. solids.	Darkening or discoloration principal difficulty to be guarded against.
Fish cakes	Solid pack	10		75	240	460 cans to batch (200 lb. potato, 100 lb. fish).	Green mountain potatoes best variety in fish cakes. Discoloration caused by over-processing.
Fish roe:							
Alewife (river herring).	3 percent (sometimes hot water used).	8	(211 x 300)	50	240	1 case 48/8 oz. cans per 20 lb. bucket "green" roe.	From 13½ to 15 oz. green roe required as fill in weight to give drained weight 16 oz. Variation depends on condition of roe.
		16	(307 x 400)	60	240		
"Deep sea" (Cod & haddock).	3 percent	14	(300 x 407)	75	240	400 cans to 300 lb. roe	Fill of cans must be watched carefully. Leave ½ in. headspace in filling.
Shad	¼ oz. salt	7¾	½ oval	110	230	26; 6 lb. per case 24/½ ovals.	Roe must be fully developed but not over ripe. If roe is too ripe, is watery and lacks flavor. If too green is hard and tough.
				55	240		
				90	240		

BRINES AND OTHER ADDED INGREDIENTS

Brines, oil, sauces or other similar ingredients are added primarily to give certain flavors to the canned product and to improve or bring out the natural flavor, but they have other uses. They may reduce the amount of processing (sterilization) required by: (1) Facilitating the transfer of heat as in canning "wet pack" shrimp, or (2) by lowering the hydrogen–ion concentration (pH) through the use of tomatoes as in packing "Manhattan style" clam chowder. They also fill the can more completely, reducing the amount of air space and therefore the possibility of corrosion inside the container. While some of these ingredients may serve incidentally as fillers, increasing bulk and weight, their use in excess, or primarily for this purpose, is regarded as adulteration under the provisions of the Federal Food, Drug, and Cosmetic Act[6].

BRINES

Brines may be used in canning to wash the raw material, aiding in the removal of blood or slime previous to canning, to improve the texture of soft fleshed fish, and to flavor the product. Only salt of the highest quality should be used for canning purposes. The analysis of the salt should indicate less than 1 percent chemical impurities, such as salts of magnesium and calcium, and it should be free from mechanical impurities such as dust or moisture. Cruess (1938) stated that salt of a small even grain is desirable, especially when added to the product dry and that discoloration of the brine and precipitation in the can is caused by iron compounds in the salt. During boiling or sterilizing, calcium salts may cause the formation of a white precipitate and a toughening of the product. Boiling transforms calcium bicarbonate into calcium carbonate, which is precipitated. The presence of excessive amounts of sodium and magnesium sulphates, or other sulphates, may result in a bitter flavor.

Weak brines are generally used in canning, varying from 3 to 5 percent in salt content. They may be made by diluting a stock saturated brine or by the addition of the proper weight of salt to an amount of water which will furnish a brine of the desired strength. The water used should also be as pure as possible, free from chemical impurities or micro–biological contamination. It is good practice to boil the brine before using to precipitate chemical impurities and reduce the possibility of contamination. Any precipitation should be removed by filtration.

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[6] Act of June 25, 1938, 52 Stat. 1040; Title 21, U. S. Code, Sec's. 341-343.

The canner should not depend solely on the use of a formula but should also test each batch of brine by hydrometer. Two types of hydrometer may be used, the Baume hydrometer and the "salinometer." If the reading of the Baume hydrometer is multiplied by 4 it will correspond approximately with the salinometer reading. A brine registering 100° salinometer will contain approximately 25 percent salt by weight.

OILS

The two vegetable oils most used for canning are cottonseed and olive oil. Peanut, corn, soy and peach–kernel oil are or have been used in canning, but only occasionally and in smaller quantities.

Olive oil is used principally in the European fish–canning industry, while cottonseed oil is favored almost exclusively in the United States. The domestic supply of olive oil is small and is absorbed by other markets; also, its flavor is somewhat more pronounced than that of cottonseed or imported olive oil and the canned products to which it has been added have not been favorably regarded in some markets on this account. Imported olive oil is too highly priced for general use and the flavor of high grade cottonseed oil is preferred in such packs as tuna and domestic sardines. It is difficult to compare high grade cottonseed and olive oils. About all that can be said on the subject is, that cottonseed oil is of excellent quality and perfectly satisfactory to those who have not acquired a taste for olive oil.

U. S. Standard cottonseed oil is the oil obtained from the seeds of cotton plants and subjected to the usual refining processes; it is free from rancidity, has a refractive index (25°C) not less than 1.4700 and not exceeding 1.4725, and an iodine number not less than 104. and not exceeding 110. "Winter-yellow" cottonseed oil is expressed cottonseed oil from which a portion of the stearin has been separated by chilling and pressure (Leach, 1920).

Only the highest grade of refined cottonseed oil should be used in the canning of fishery products. A refined oil of ordinary grade is apt to injure the palatability of products to which it is added. Specially refined oil, of the "salad oil" type is more expensive; however, it eliminates the distinctive flavor and characteristic odor disliked by the consumer. The addition of an ordinary grade of cottonseed oil to "oil pack" canned fishery products is false economy, giving such goods the reputation of being inferior in quality. Maine "quarter–oil" sardines were classified as a "cheap" article largely because of the grade of cottonseed oil used by some of the packers. These packers, finally recognizing that the use of such oil was hurting the sale of their product, have changed to a higher grade with the result that the pack is finding a better market and production is increasing over the former level.

U. S. Standard olive oil is the oil obtained from the sound, mature fruit of the cultivated olive tree (*Olea europoea* L.) and subjected to the usual refining processes; is free from rancidity; has a refractive index (25° C.) not less than 1.4660 and not exceeding 1.4680; and an iodine number not less than 79 and not exceeding 90. *Virgin olive oil* is olive oil obtained from the first pressing of carefully selected, hand-picked olives. There are a number of grades of edible olive oil, the quality depending on the variety of olive, its ripeness when picked, the method of handling and length of time that the olives are stored before pressing (Leach, 1920).

Research workers in the Norwegian canning industry have given considerable attention to the relationship between the quality of the olive oil and the quality of the canned product. It has been determined that the highest grades of olive oil must be used if the pack is to be sold as a superior quality product (Lunde, 1933).

Salmon oil is the only fish oil used as an added ingredient in the canning of fishery products. The use of salmon oil is a recent development confined at present principally to the Columbia River area. Oil is added to chinook salmon of all grades. This use is for the same reason as the addition of oil to tuna and sardines, namely to insure a uniform oil content and enhance the appetite appeal. Only the highest quality of salmon oil may be used. The oil should be clear deep red in color with a minimum free fatty–acid content. Oil added to canned salmon is made only from fresh salmon trimmings.

VINEGAR AND SPICES

Some fish is packed in spiced vinegar sauce, principally mackerel fillets and sardines. To maintain a uniform standard of quality close attention must be paid to the ingredients used in making the sauce. The vinegar used should be white distilled pickling vinegar with an acetic–acid content of 6 percent. The flavor of this vinegar will be found too sharp if used undiluted but it is better to dilute a strong vinegar according to formula than to use a vinegar of lower acid content. The so–called cider vinegars are not recommended since their acetic–acid content is variable and it would be necessary to determine the acid content of each lot of vinegar by titration to obtain a sauce of standard flavor and quality. Cider vinegars also contain organic compounds which may affect the flavor of the product. A "16 grain" malt vinegar is sometimes used. Any vinegar purchased for spiced vinegar sauce or in the preparation of mustard or other sauces, should be clear in color, free from mustiness or "off odors," and guaranteed to contain a definite percentage of acetic acid.

The canner should not depend on ready–mixed pickling spices because the proportions of spices in such mixtures are not always uniform, and it may be difficult to secure the desired flavor. Such spice mixtures are often stale or of cheaper grade and, especially in the case of ground spices, may even be adulterated by the addition of starch or vegetable fiber. Spices must be fresh and pure. Whole spices should be bought separately and mixed by the packer to secure the best results. Ground spices should be free from adulteration and where possible samples should be subjected to micro–analytical examination before purchase to determine the quality.

MUSTARD SAUCE

This product is used principally in packing California and Maine sardines and consists of a mixture of ground mustard seed or mustard flour with salt, spices, and vinegar. A standardized formula is not followed but mustard sauce used in canning must comply with U.S. standards for prepared mustard which require that it should contain not more than 24 percent of carbohydrates calculated as starch, nor more than 12 percent crude fiber and not less than 5.6 percent nitrogen.

Mustard sauce may be prepared by the fish canner but often is supplied by pickle manufacturers or dealers in spices and condiments. Some of the sauce has been of very low grade, especially where it has been sold on a price basis. A good grade of mustard sauce enhances quality, increasing the appetite appeal. The following specifications must be followed to prepare mustard sauce of desirable quality: (1) Mustard sauce must be made from clean mustard seed. (2) The other ingredients, salt, vinegar, and spices shall be fresh and unadulterated. (3) Mustard sauce must be made without starch, gums, or any other artificial thickening agent. (4) The amount of mustard seed used shall not be less than 5 percent of the total weight of the sauce.

The principal spices used in mustard sauce are cayenne, or red pepper, and turmeric, other spices varying with the individual formula. The proportion of cayenne and turmeric is increased in some instances to mask a low mustard seed content. Excessive use of these spices should be regarded as adulteration.

The vinegar content of mustard sauce should be closely controlled by the canner. If the acid content is higher than 1.5 percent, calculated as acetic acid, the sauce may cause the containers to become "hydrogen swells" especially where the pack is stored at warm temperatures. This also applies to tomato sauce.

TOMATO SAUCE

This sauce is used most widely in packing California sardines but it is also added as a condiment to some packs of canned herrings, mackerel fillets and canned smoked fish specialties. Tomato sauce used in canning sardines is previously prepared, seasoned with salt and is packed in 5 gallon square cans. Those sardine firms which do not pack tomato products buy a tomato sauce specially made for fish canning. In this instance, the sauce is prepared without salt, which is added when it is warmed for use in canning.

A tomato "fish sauce" is a type of ketchup made of screened tomato pulp, vinegar, spices, onions and salt. A variety of spices may be used, depending on the individual formula, but bay leaves and cloves form the most popular combination. Sugar cannot be included as an ingredient as it would caramelize at the high temperatures used in processing, discoloring the sauce.

Tomato sauce used in canning should be made from whole, ripe tomatoes. Mold counts and worm fragments should be well below the maximum permissible under State regulations or those of the U.S. Food and Drug Administration. The specific gravity of the sauce should be 1.07 or better as a thin consistency adds neither to the appearance nor to the flavor of the pack. The addition of starch or other thickening agents, or of foreign pulp such as apple or pumpkin, is regarded as an adulteration.

PACIFIC SALMON[7]

The salmon canning industry is located on the Great Circle of the North Pacific coastal area extending from the State of Oregon to northern Japan, although salmon are caught commercially in the United States as far south as Monterey Bay in California. The total annual world pack of canned salmon in this area averages about 10,000,000 cases of 48 one-pound cans. Alaska is the most important of the political divisions in this area, accounting for almost 90 percent of the United States pack of canned salmon and 60 percent of the world production. While methods of preservation such as freezing, salting and smoking are important, more salmon are canned than are preserved in all other ways.

Salmon are also caught on the Atlantic Coast of North America but are not canned in quantities of commercial importance as the supply of raw material is limited and the flesh usually has a very light color after canning.

SPECIES OF PACIFIC SALMON

The first and most important fact to be considered in connection with salmon canning is, that not one but five species of salmon are canned. To understand the conduct of the industry, from methods used in catching to sale of the finished product, this must be kept in mind. A discussion of these species is therefore required.

The Pacific salmon are all included in the genus *Oncorhynchus*. With them the fishermen incorrectly group the steelhead trout, which really belongs to the closely-related genus *Salmo*. As long ago as 1731 the species of *Oncorhynchus* were first made known by Steller, who, almost simultaneously with Krascheninikov, another early investigator, distinguished them with perfect accuracy under their Russian vernacular names. In 1792 Walbaum adopted the vernacular names in a scientific nomenclature for these fishes.

The 5 species are: (1) *Oncorhynchus tschawytscha;* chinook, king, spring, tyee or quinnat salmon; (2) *Oncorhynchus nerka;* red, sockeye, blueback, quinault or redfish; (3) *Oncorhynchus kisutch;* medium red, coho or silver salmon; (4) *Oncorhynchus gorbuscha;* pink or humpback salmon; and (5) *Oncorhynchus keta;* chum, keta, calico or dog salmon. The first common name given is that used where the canning of the species is most important, followed by names used less often, while the last names listed are those applied by fishermen in some areas but seldom or never to the canned product.

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[7] This section prepared by R. W. Clough, Chemist, E. D. Clark, Director, Northwest Branch, National Canners Association, and Norman D. Jarvis.

The various species, while closely related phylogenetically, differ greatly in size, coloration, duration of life cycle, the behavior of the young fish and the character of the food of the adult. A brief description of the species, useful to the packer for identification purposes, is presented in table 10.

CHINOOK

The largest of the Pacific salmon is the chinook or king salmon (*O. tschawytscha*). It has a deep, thick body with a small head. The back is a deep olive green and the sides and belly are a silvery hue, the back, dorsal fin and caudal fin are marked with a varying number of round black spots, and the sides of the head have a peculiar tin-colored metallic luster. The fish has an average weight of about 22 pounds but specimens weighing from 80 to 100 pounds are occasionally taken.

As a rule the flesh is of a deep salmon red but it may vary from this shade to white among different specimens in certain fishing areas. Even within the individual this color variation may exist.

Although of the 5 species the chinook salmon is the most widely distributed geographically, in general it is native to a few great rivers. The most important of these is the Columbia, which supplies approximately two-thirds of the world's production of this variety in the canned pack.

RED

The red or sockeye salmon is relatively small in comparison with other species of salmon, averaging about 6½ pounds, with a maximum of 12 pounds. The body is slender with the head small and roundly pointed. The color of the back of the head and body is a clear bright blue above with the rest of the body silver without spots or minor markings.

The flesh is a deep orange red, while the oil is red. The texture is firm, as a rule. The attractive appearance and flavor made this species a "fancy" pack early in the history of the industry. As a result the demand exceeded the amount available and it was necessary to can other species of salmon with lighter colored flesh in order to supply the market. This difference in color gave rise to rumors that other species of fish were being dyed and sold as salmon. Even if this were permitted by law, the technical difficulties in successfully dyeing the flesh are practically insurmountable and the added packing cost would make it uneconomical.

TABLE 10.—*Description of the five species of salmon and the steelhead trout before canning*

Scientific name and common name	Weight		Length	Shape of body	Size of scales	Color of raw flesh	Distinguishing marks
	Maximum	Average					
	pounds	*pounds*	*inches*				
Oncorhynchus nerka (red salmon)	12	6½	17 to 32	Symmetrical	Medium	Deep red	No spots
Oncorhynchus tschawytscha (chinook salmon)	100	22	24 to 60	Robust	Large	Red to white	Back, dorsal fin, and tail covered with round black spots
Oncorhynchus kisutch (medium red salmon)	30	9	20 to 36	Elongated and flattened	Medium	Light red	Faint spots on back, dorsal fin and upper part of caudal fin
Oncorhynchus gorbuscha (pink salmon)	14	4½	15 to 27	Slender	Small	Pink	Large, oblong, black spots all over tail and on back
Oncorhynchus ***keta*** (chum salmon)	30	9	25 to 37	Robust	Large	Light pink	No spots
Salmo gairdnerii (steelhead trout)	45	12	--------	Slender	Large	Pale pink	Small black spots on dorsal, adipose and caudal fins

MEDIUM RED

This is the silver salmon, so-named because of the general silvery color of the body. It has acquired the name "medium red" from the color of the flesh, which is usually somewhat lighter in shade than that of the red salmon, but deeper than the chinook.

This species is the second largest of the Pacific salmons in size. It has an average weight of 9 pounds and a maximum weight of 30 pounds. It has some resemblance to the chinook and is sometimes mistaken for that variety but the spots are fainter, fewer in number, and smaller in size. While it is generally distributed in the coastal streams from the Eel river, California northward, the silver salmon appears late in the season so that comparatively few are canned.

PINK

The pink salmon is the smallest of the Pacific salmons but is the most abundant and furnishes more than 40 percent of the world's supply of canned salmon. The pink salmon averages 4 pounds in weight and rarely exceeds 8 pounds.

The shape of this fish is slender, with a small sharp head and relatively large tail. The color of the back is a light olive green. The body has numerous black dots, particularly on the tail. Although the flesh is rather light in color, the delicate flavor, tender texture and high food value have made it quite popular, while the abundance has permitted the price to remain low. The pink salmon is found in nearly all salmon areas from Puget Sound northward.

CHUM

The chum salmon is occasionally known as keta or white salmon. The average weight is about 8 pounds while the maximum weight is 16 pounds. When the chum salmon first appears along the coast the color is dirty silvery, immaculate or sprinkled with small black specks. The fins are dusky and the sides show faint traces of gridiron–like bars. Later in the season the male is colored brick red or blackish, and the jaws are greatly distorted.

The color of the flesh in the canned product ranges from a light pink to a yellowish white. The texture of the flesh is firm and the oil light yellow in color. As a rule this species when caught has little color and less oil than other varieties, consequently canned chum salmon brings a lower price although it is rather high in food value and can be made into appetizing cooked dishes.

STEELHEAD TROUT

The steelhead trout (*Salmo gairdnerii*) is commonly considered as one of the salmon by fishermen and is therefore included here, though it does not belong to the genus *Oncorhynchus*. It is closely related to the Atlantic salmon (*Salmo salar*).

The steelhead has a slender body with a small head. The common name of this species is supposed to have originated from the hardness of the head. Numerous small black spots appear on the head and on the dorsal, adipose and caudal fins.

While the usual specimen weighs from 8 to 15 pounds, individuals of 45 pounds or more are sometimes taken. The color of the raw flesh is a pale pink. This fades almost to white in the canned product which is very rich in pale yellow oil. Very little of this species (about 0.3 percent of the total pack) is preserved by canning due to its lack of color. The steelhead trout has a wide range and is believed to be most abundant in the Columbia River area.

FISHING SEASONS

Only when the Pacific salmon gather in schools for their spawning migration may they be taken in quantity by the fisherman. It is during this comparatively brief period that they are in best condition for they are neither immature and feeding, nor has the fat and protein content been reduced by a long stay in fresh water.

Fishing seasons are established by State law in Oregon and Washington, and by Federal regulation in Alaska. The seasons vary with the different areas and are fixed to cover the periods of greatest abundance. In some areas closed periods of a varying number of hours each week within the season are provided to permit sufficient escapement to the spawning beds for conservation purposes. Likewise local areas may be closed for an entire season.

Most of the Alaska red salmon catch is taken and canned in a period of a little more than a month. Particularly in Bristol Bay, the run appears almost invariably on schedule at the end of June. Red salmon usually run rather early in the season in all salmon fishing areas and few are taken after August.

The pink salmon, like the red, make a sudden appearance in coastal waters. The catch attains great volume quickly, then rapidly declines as the main runs enter the streams. The run begins somewhat later than that of the red salmon and is usually over by the middle of September.

Chum salmon are caught at the latter end of the season with the exception of a few Alaska districts which support an early run. They appear only in autumn months on the Oregon–Washington coast, where they are sometimes called "fall" salmon for this reason.

Chinook or king salmon are caught over a longer season than other species, and are taken in the Columbia River from May 1 to November 30, but the canned pack is made almost entirely from May to August. In many other areas the run occurs before the red salmon appear.

Medium red or silver salmon are also caught during a long season, but canning of this species is largely confined to late summer and early autumn.

FISHING GEAR AND METHODS

The types of gear used and methods following in catching salmon are influenced by the fact that salmon are taken only on the brief spawning run, that they must be taken as cheaply as possible, and must reach the cannery in good condition if canned salmon is to be sold in large quantities at a reasonable price.

Chinook and medium red (silver) salmon may be caught at sea by trolling a spoon lure but red, pink and chum salmon will not take a hook and can be caught only by other types of gear when they approach the coast on their spawning migration. Troll caught salmon are usually absorbed by the fresh and cured fish trade, with only a minor portion being sold for canning.

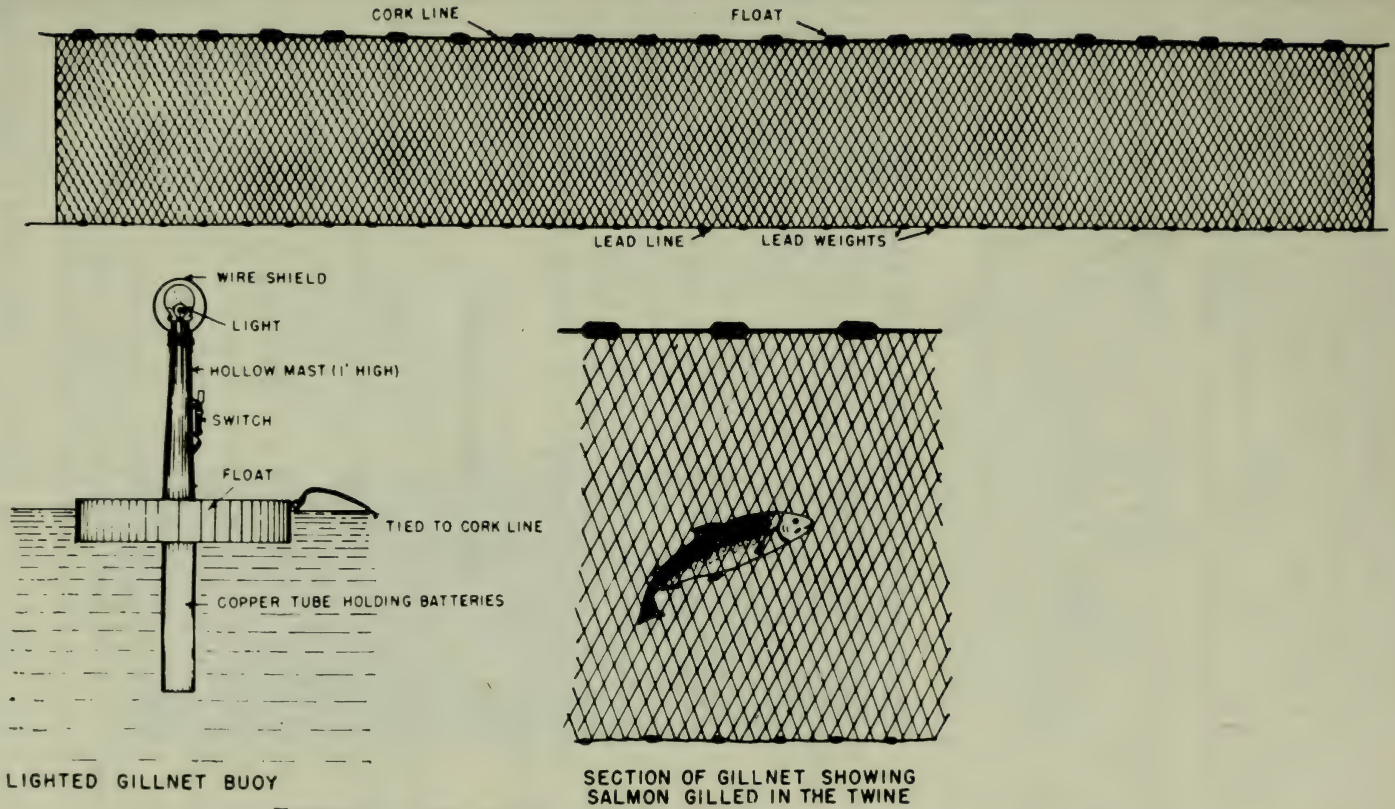
GILL NET FISHING

The gill net (Fig. 12) was the first form of fishing gear used in the salmon fisheries of the Pacific, with the exception of certain types in long use by the natives. The terms "drift" and "set" clearly differentiate between two kinds in general use. Both have floats at the top and lead sinkers at the bottom to hold the net upright in the water with the meshes properly distended in order that the moving salmon may thrust its head through and be caught behind the gills or be "gilled in the twine." In order that the salmon may hit the net hard enough to be caught it must not see the net, so this fishery is carried on at night or in muddy waters.

Drift gill nets are laid out roughly in the form of an "*L*" across the estimated path of migration. One end is marked with a buoy lighted at night and the other is retained by the drifting boat. From time to time the nets are drawn into the boat over a wooden roller and the fish removed. This is done rather frequently since the fish, caught in the gills, usually drown and begin to spoil and, furthermore, being dead or helpless, they are often preyed upon by other fish or seals.

Set gill nets frequently are smaller than the drift nets and have one or both ends staked or anchored. In form and principle they are the same as drift nets. The length, depth and size of mesh are prescribed by regulation as is true of the specifications of other types of nets and seines.

Various modifications of the gill net are in use, particularly on the Columbia River, to catch the different salmon which vary



LIGHTED GILLNET BUOY

SECTION OF GILLNET SHOWING SALMON GILLED IN THE TWINE

FIGURE 12.—Salmon gill net. (By O. E. Shostrom. Courtesy, Northwest Branch, National Canners Association.)

greatly in size and so would not all be caught in the one size of mesh (Puustinen, 1930). The trammel net (Fig. 13) consists of 3 separate webs attached top and bottom to the same cork and lead lines, a small–mesh web being sandwiched between 2 webs of larger mesh called "trammels." The salmon swims through the large mesh of one trammel, hits the fine meshed net and pushes it through a large mesh of the second trammel to form a bag in which it is entrapped.

The "apron" gill net combines 2 separate fishing units, a "back–wall" and the "apron" into 1 net. They are hung hinge-fashion from the same corkline, the back–wall hanging vertically while the apron floats out horizontally forming an L shaped contrivance so that salmon veering from one may be caught in the other. Some of the nets in use are very complicated embracing both the apron and trammel principles in the one net.

HAUL-SEINE OR BEACH-SEINE FISHING

As indicated by the name haul seines or beach seines (Fig. 13) are usually hauled on the gravel beach at Karluk on Kodiak island or on the numerous sand bars found in the lower Columbia River at low tide. Buildings are erected on piles on these sand flats, in which the men and horses take refuge when the bars are covered with water. Operations begin as soon as a part of the bar is above water. The net, shallow at the ends and widening out to the "bunt" in the middle, is laid out in a large semi-circle, after which the two ends are brought to the beach, and the net is hauled out either by several spans of horses, as on the Columbia River, or by steam engine as at Karluk.

PURSE-SEINE FISHING

The purse seine is one of the most important types of gear in the taking of the salmon in general use in Puget Sound and on the coast of Central and Southeastern Alaska, proving very effective in these deep waters (Fig. 14). The seines vary from 50 to 250 fathoms in length, with a 3½– to 4–inch stretch mesh and a depth varying from 125 to 250 meshes. The foot line is heavily leaded and the bridles holding the purse rings are about 10 feet long. The purse line is made of 1½ inch hemp rope and is rove through 5–inch purse rings made of galvanized iron.

The purse seine vessels are built with square sterns and on an elevated section moving about a pivot is set a platform upon which the purse seine is stowed and from which it is payed out over a long roller.

When the lookout sights a school of fish a skiff is launched to hold one end of the seine, while the seiner quickly circles the

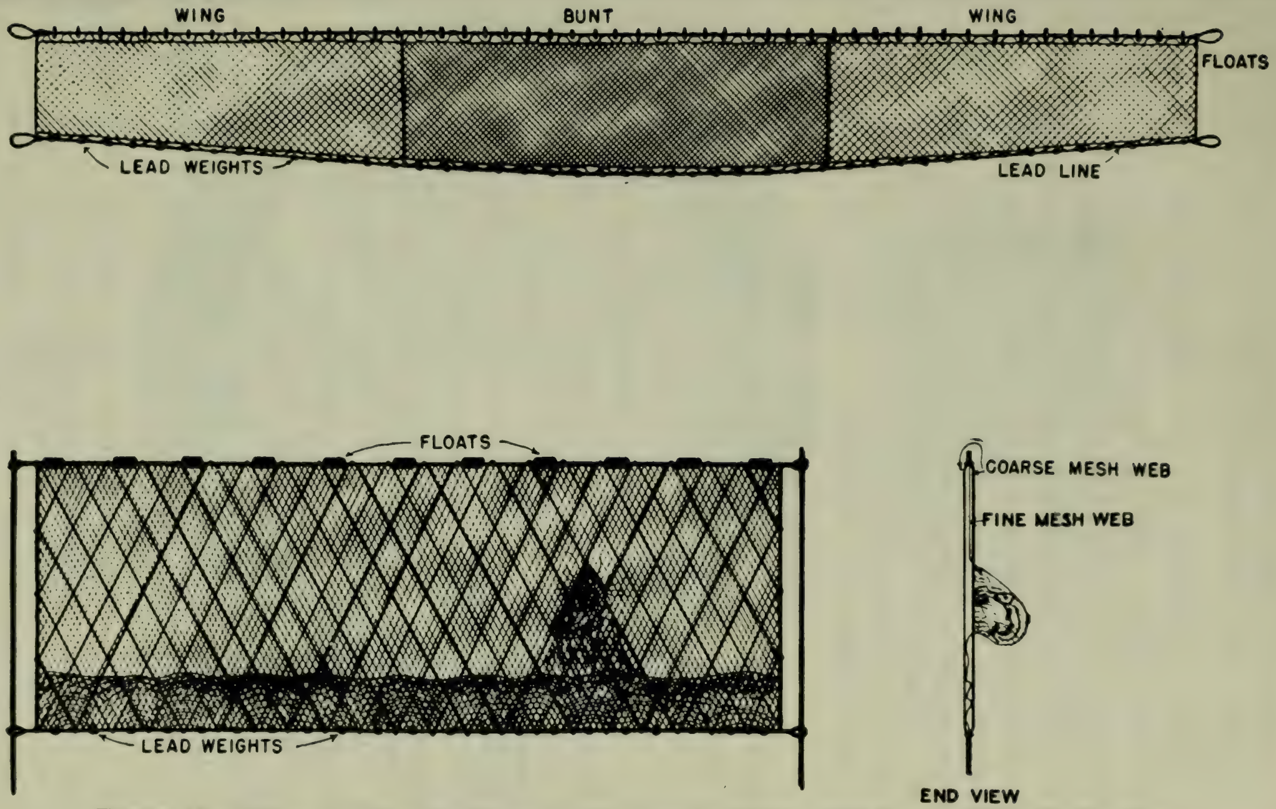


FIGURE 13.—Salmon beach or haul seine (above) and trammel (below) net. (By O. E. Shostrom. Courtesy, Northwest Branch, National Canners Association.)

school, paying out the seine. The corks hold the head rope at the surface and the net hangs straight down to the leaded foot line. From the foot line hang purse rings by short ropes called bridles and through these rings passes the rope for pursing the seine at the bottom.

As quickly as possible, the two ends of the net are brought together and the two ends of the purse rope are drawn in by a power winch until the seine is well pursed at the bottom and the fish impounded in the net which is now in the form of a bag supported by the cork line and the boat. The power winch also draws in the net until the circular area is only a few feet in diameter. The salmon are then lifted out by means of a dip net attached by appropriate tackle to the hoisting boom. A fisherman lowers the net into the seine by its long handle, scoops up a load of salmon, and guides the apparatus as it is lifted over the vessel. The dip net is then tripped and the salmon allowed to fall into the hold.

POUND NETS OR TRAPS

Pound nets or traps (Fig. 15) have proved very effective when well located and appropriately constructed, but they are expensive to build, and in exposed positions are frequently wrecked by storms and floating debris. This type of gear is stationary, but may be either driven or floating, depending upon the character of the bottom and on the depth of water. The driven trap was the first type used. Long wooden piles are driven into the bottom in a pattern designed to turn the migrating salmon from their course and lead them into an outer heart, an inner heart, a pot and a spiller. Webbing and wire netting of a mesh fine enough to stop and turn the salmon is hung upon the piling of the lead and hearts from slightly above high water to the bottom. The pot and spiller are furnished with a webbing bottom so that these two parts of the trap are in reality huge bags in which the fish may be retained alive until needed at the cannery.

The floating trap is constructed along the same lines but is suspended from large floating logs anchored in place by huge concrete anchors and weights. Since the mesh walls do not extend to the bottom it is necessary to floor the hearts with webbing as well as the pot and spiller.

Some traps are designed to fish only from one direction and others from two. Some have one spiller and others two. Traps may have but one heart or be supplied with variously shaped "jiggers" of meshed walls to turn back escaping salmon.

The salmon are removed from the trap spillers to waiting scows or boats by a rectangular net apron called a "brailer," which is attached at one end to the scow or boat. The other end is fastened

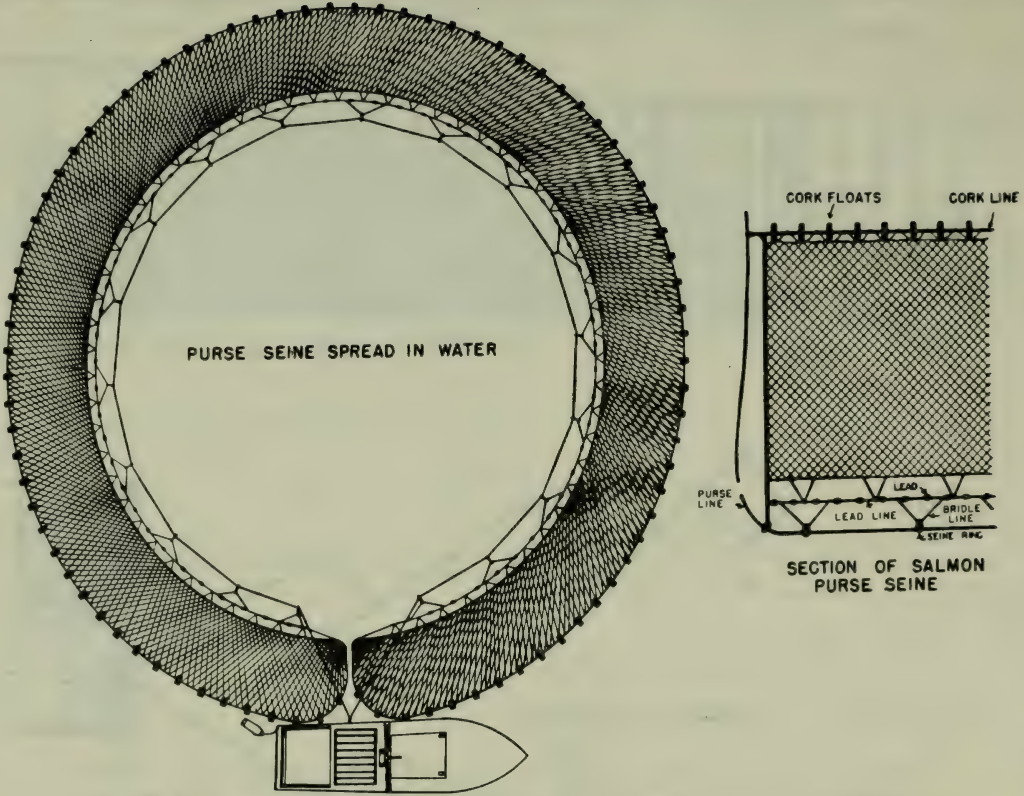


FIGURE 14.—Salmon purse seine. (By O. E. Shostrom. Courtesy, Northwest Branch, National Canners Association.)

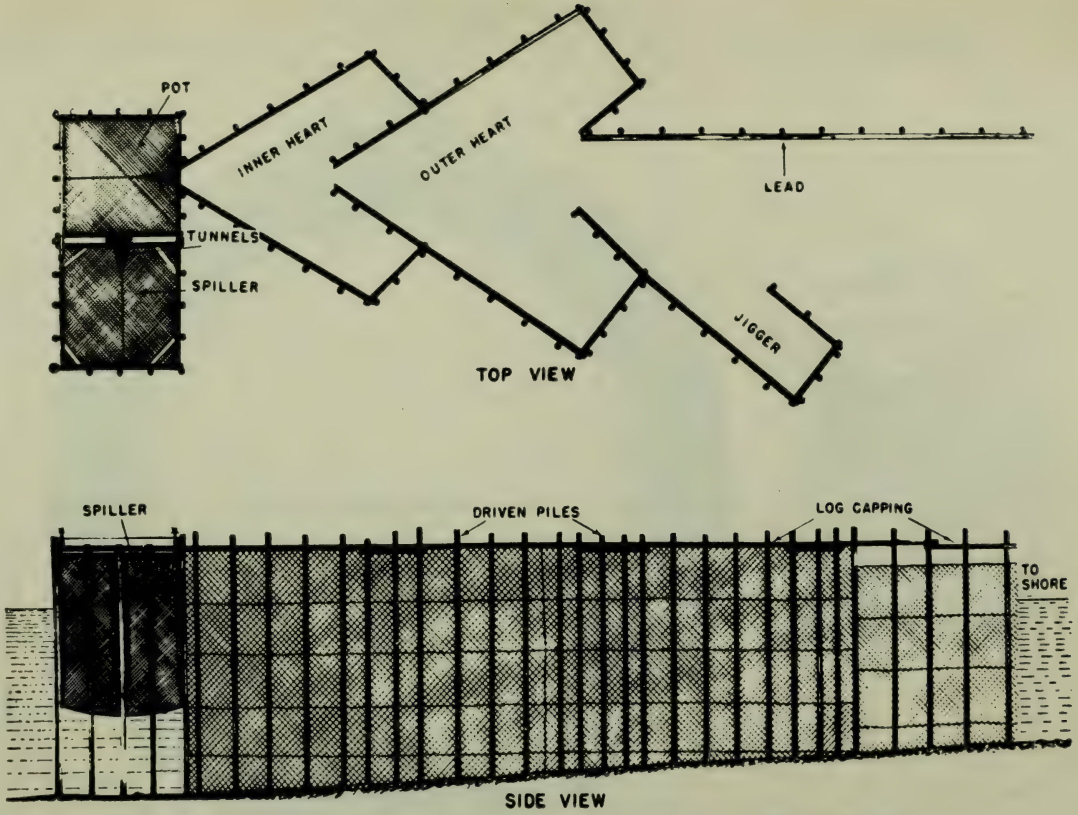


FIGURE 15.—Salmon trap with driven supporting piles. (By O. E. Shostrom. Courtesy, Northwest Branch, National Canners Association.)

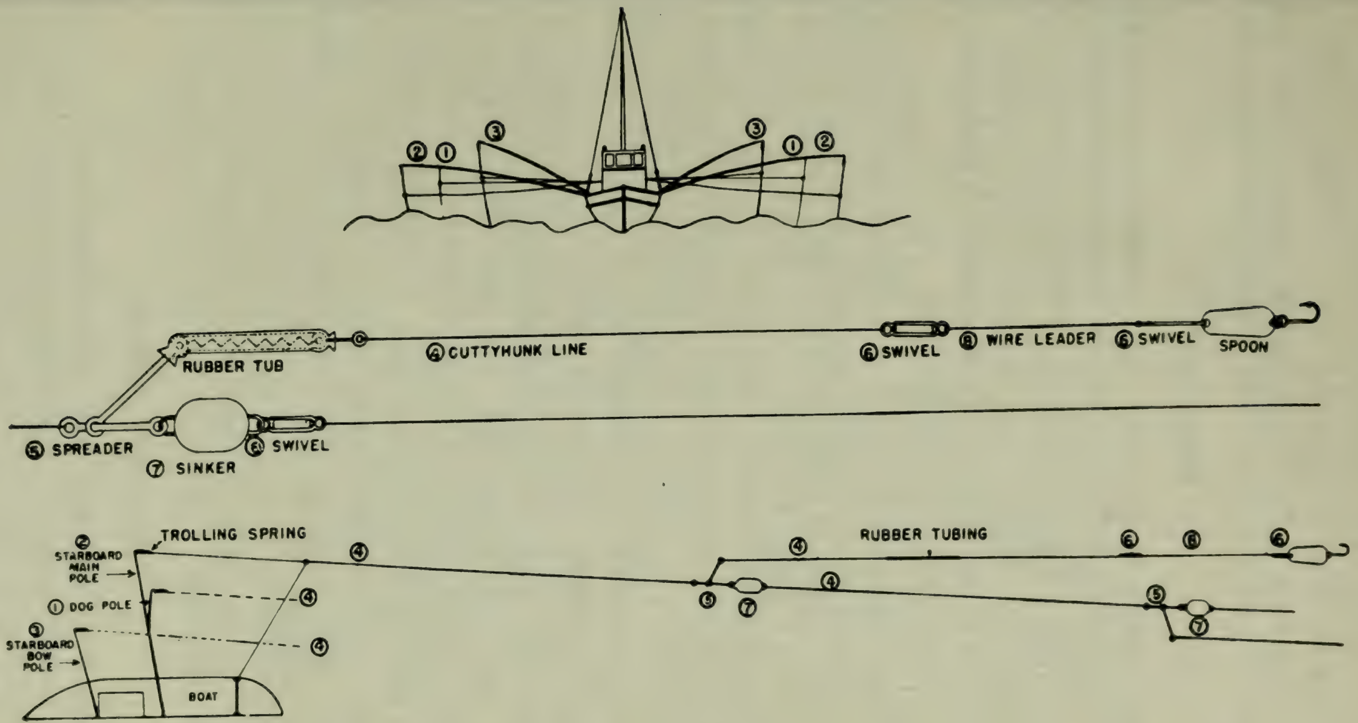


FIGURE 16.—Salmon trolling; showing detail of trolling gear. (By O. E. Shostrom. Courtesy, Northwest Branch, National Canners Association.)

to a long iron pipe from which runs a line through a block on the derrick of the tug or tender to a winch. The apron is let down, drawn across the floor of the spiller and then raised to spill out the fish on the scow or tender. Repeated operation of the brail soon empties the spiller even though it may contain several thousand fish.

TROLLING

Although angling is one of the oldest methods of catching fish its use commercially for the taking of salmon is comparatively recent. Trolling can be carried on throughout a longer period of the year than fishing with any other form of gear (Fig. 16). Today trolling is followed from Monterey Bay, California, to Prince William Sound, Alaska, and the number of boats engaged is second only to those of the gill–netters.

Trolling boats have increased in size and in mechanical complexity. They range up to 50 feet or more in length, are exceptionally seaworthy and so compact and easy to handle that usually only one man is required to operate them. The standard trolling rig consists of 6 poles, 3 on each side, arranged as follows: A rather short pole near the bow of the boat, a long pole hinged to the deck near the mast and a short pole lashed to the long one at a point about two thirds of the distance from its base to its tip. Each of the 6 poles carries a fishing line equipped with several hooks so arranged by spreaders that as many as 30 hooks may be actively engaged from a single boat.

Many of the boats have power line–pullers which are actuated by the strike of a salmon and the fish are mechanically drawn in and held until the fisherman can pull them aboard. They are immediately cleaned and placed in bins of crushed ice. Since most of the troll–caught fish are still feeding, their digestive tracts are filled with food and unless they are promptly dressed rapid deterioration sets in. The bellies become soft and the general quality is lowered. Fish caught by this method are in demand mostly for mild–curing and the fresh fish market. The rapid increase of trolling and purse–seining on the feeding banks off the coast has resulted in the taking of many small and immature fish and threatens to seriously deplete the supply of chinook and coho salmon.

REEF-NET FISHING

When the white men first came to the Pacific Northwest they found the natives along the coast using various methods and devices for catching the salmon. Some of these were very ingenious. The most important native Indian salmon fishing gear was the reef net constructed of willow bark netting and ropes of twisted

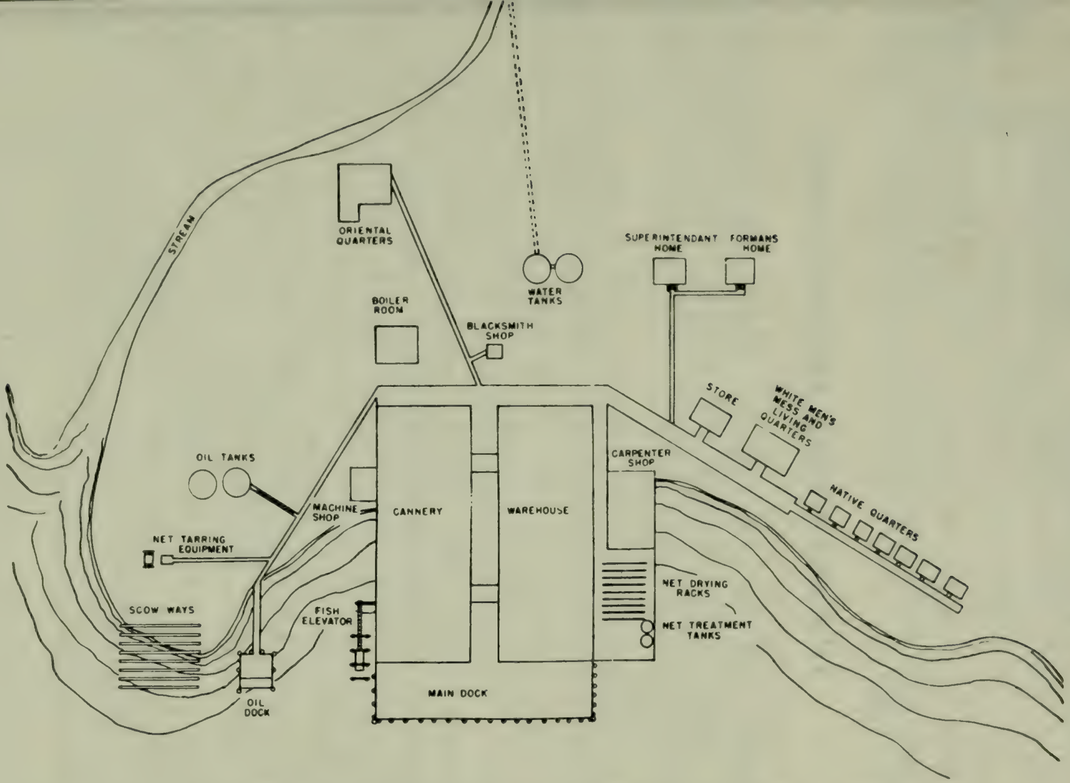


FIGURE 17.—The general layout of a typical salmon cannery. (By O. E. Shostrom. Courtesy, Northwest Branch, National Canners Association.)

withes. The nets, some 25 feet in width and 40 feet in length were fished between 2 canoes lashed to logs and anchored over the top of a reef. Leads and aprons of kelp and willow led the salmon to the net which was lifted from time to time and the captured fish placed in the canoes. It is reported that at times as many as 3,000 fish were taken on a single tide.

The reef net has recently been adopted on a rather wide scale by white fishermen in the Puget Sound area, where it is being substituted for the fish trap which has been forbidden by law in the State of Washington. Webbing and rope have been substituted for materials used by the Indians but the principle of operation is the same.

TRANSPORTING AND RECEIVING

Transporting the catch from fishing grounds to the cannery is expensive, and one of the biggest problems in salmon canning. The quality of the finished product depends considerably upon the method used and care exercised in the handling and transportation of the raw material.

Large canneries (Fig. 17) may require as many as 6 or 7 large–sized power boats known as tenders, as well as an equal or greater number of scows, for bringing the catch to the cannery. Salmon from the traps are "brailed," or scooped, onto scows, or directly into the holds of tenders. In the case of purse–seine and gill–net boats the fish are taken from the net into the fishing boat. Fishermen occasionally take the salmon to the cannery in their fishing boats, but much time is lost. It is also more difficult to control the quality of the raw material when the fishermen land their own catches.

Upon arrival at the cannery, salmon are unloaded onto elevators of the endless chain–bucket type. The preferred system is to sluice fish from the scow onto the elevators by a strong stream of water. Salmon may be unloaded more rapidly by this method with less handling. When salmon are unloaded from the holds of tenders or from purse seiners and other fishing boats, it is necessary to pitch them onto the elevator, using a "peugh." If this method must be used, salmon should be peughed only through the head.

Salmon usually are unloaded from the elevator into a series of water–tight bins all sloping to one point, which leads to the butchering machine conveyor. The bin doors may be short boards fitting into grooves. In some plants the bin entrance may be provided with a short chute having an undercut gate which is forced up into the stream of fish from below, controlling their passage to the "iron chink" (Fig. 18).

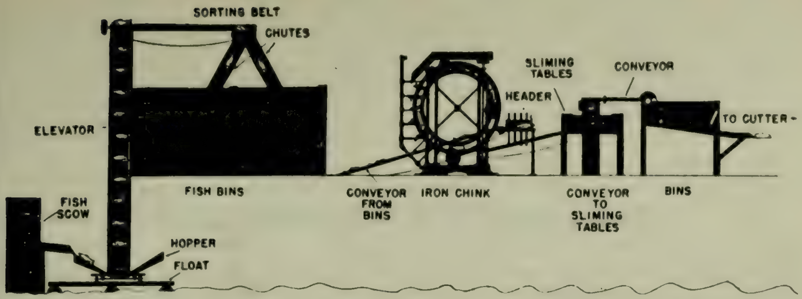


FIGURE 18.—Salmon canning; unloading and butchering. (By O. E. Shostrom. Courtesy, Northwest Branch, National Canners Association.)

GRADING

Salmon are graded as they are unloaded from the boats, each grade going to a different bin. At the present time the principal system of grading is by species, locality of capture and type of gear. The "spring pack" of Columbia River chinook salmon is the only instance in which quality factors such as color of the raw flesh, amount of oil and freshness are used in grading salmon previous to canning.

DRESSING AND WASHING

Formerly, all salmon were cleaned and dressed by hand, usually by Chinese as they were considered the most satisfactory labor for the task. But now these workers have been displaced by a machine known as the "Iron Chink" because it is doing their work (Fig. 18). This machine is able to dress and clean as many as 3,600 fish in an hour. The chinook or king salmon which are large and extremely variable in size are still cleaned by hand, the only portion of the pack in which the old method is still used.

The salmon, traveling by conveyor from the fish bins are fed to the iron chink at the rate of about 60 per minute. The first operation of the machine is to remove the head with a revolving knife. The headless body is then caught between 2 revolving drums which grip and hold it firmly, back down and tail first. Rapidly whirling saws and knives split the belly and remove the fins and tail, while revolving brushes and sprays of water clean the belly cavity. The heads and other offal fall through a hole in the floor onto a conveyor.

After passing through this machine, the salmon is carried onto a belt conveyor through a tank of running water where it is scaled and washed by hand. Any bits of viscera, fins or other offal which have not been removed previously are trimmed away and the fish is then given a second washing. The iron chink has been improved to such an extent that there is usually little work left for this cleaning crew except to make a careful inspection of the dressed fish. The amount of loss in cleaning and preparing salmon for the container averages: Chinook 30, red, coho and chum 33 and pink salmon 35 percent of the original weight.

PREPARATION FOR THE CAN

After the washing and cleaning process, the fish are brought to the cutting machine, either by conveyor, hand trucks or by flume (Fig. 19). The salmon is cut into can–length portions by a machine which consists of a wooden vertical carrier with ledges or buckets operating on a chain. These buckets are wide enough to hold a salmon and are slotted in cross section through the ledges and outer casing, to receive gang knives. The carrier and gang knives each operate independently on individual shafts. As the buckets come into horizontal position, a workman lays a fish on each as they pass by. The salmon are then carried to revolving gang knives where they are divided in sections and slide into a

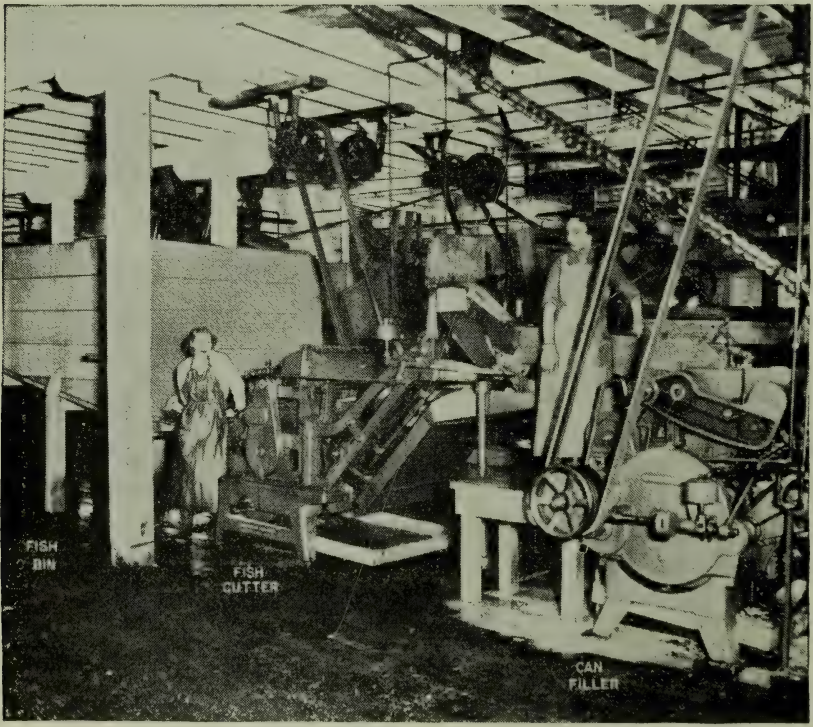


FIGURE 19.—Salmon canning line; fish bin, fish cutter and can filler. (Courtesy Continental Can Company, Inc.)

chute leading to the filling machine. The gang knives or cutters are adjusted to cut the fish transversely into sections of the correct length for the can. The tail pieces are sometimes segregated, and the meat is cut into small pieces to be used in completing the fill of cans that have not received the required amount in the automatic filling machine.

On the Columbia River and in some of the smaller canneries in other districts, especially those making the greater part of their pack in flat cans, the gang knives are operated by hand. These knives are not circular like those on the cutting machine but have elongated blades and operate after the principle of the old fashioned plug–tobacco cutter. Several knives are mounted on a single axle at a distance far enough apart to cut pieces the length of a can. A lever is fixed in position at one end of the axle to serve as a handle. In operating this gang knife, the salmon is placed in position under the knives and the handle is brought down.

The most recently equipped canneries have filling machines which take the whole cleaned fish and cut them into suitable lengths just before they reach the empty cans. In these canneries the separate fish cutter is omitted. This is an advance in salmon canning as it reduces the amount of handling.

FILLING

Automatic filling machines have replaced hand-packing except for a few small canneries or in the filling of oval or other odd–sized cans and in packing flat cans on the Columbia River.

While the first filler was capable of filling 48 cans a minute, the latest have been operated at a speed of 270 cans per minute although this rate is undoubtedly too fast for good workmanship in packing. However, a speed of 200 cans per minute is common and can be maintained.

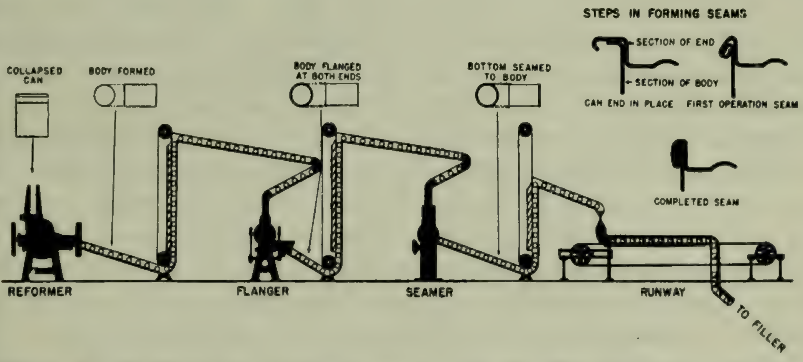


FIGURE 20.—Reforming collapsed cans. (By O. E. Shostrom. Courtesy, Northwest Branch, National Canners Association.)

Empty cans are fed into the filling machine by a conveyor from the "can loft" or reforming line as the case may be. As each can enters the machine it receives from 1/4 to 3/8 ounce salt from a receptacle adjusted to deliver the required quantity (Fig. 20).

The pieces of salmon, as received from the fish cutter, or as cut from the whole dressed body by the late model filling machine, are fed into a cylindrical measuring box with a capacity equal to that of the cans to be filled. Appropriately placed and frequently sharpened knives cut off any excess fish. A plunger then pushes the salmon from the measuring box into the can, together with an ingenious and accurately timed device called an extractor, which permits the escape of air, as the cylinder of fish enters. As soon as the extractor and plunger are withdrawn, the filled can is thrust out of the machine to pass on to the inspection table.

The various sizes of cans used in salmon canning, with the average fill in weight are: No. 1 tall (301 x 411), 16.6 oz.; 1–lb. flat (401 x 211), 16.2 oz.; 1/2–lb. flat (307 x 201.25), 8.0 oz.; 1/4–lb. flat (301 x 107), 3.9 oz.; 1–lb. oval (607 x 406 x 108), 16.0 oz.; 1/2–lb. oval (309 x 515 x 103), 7.9 oz.; 1/4–lb. oval (211 x 404 x 100), 3.9 oz. and No. 5 (602 x 403), 64.0 oz.

THE COLLAPSED CAN

One development in the manufacture of the tin can is peculiar to the salmon industry. Due to their isolated locations in Alaska most salmon canneries are at a great distance from can factories. Formerly, the larger canneries manufactured their own cans but this was not feasible for the smaller companies. It costs as much to ship empty cans by boat as filled cans, since water freight rates are based on cubic measurement.

It was found that the can bodies, before the end was rolled on, could be collapsed from a circle to form a narrow oval as viewed from the end. The collapsed can bodies are packed 360 to the case which holds only 48 completed cans. The ends for 1200 1–pound tall cans are packed in a single case. This development was so revolutionary that practically all salmon canneries ceased making their own cans. With collapsed cans and knock–down cartons much less can storage space was needed in the canneries.

A can reforming line (Fig. 20) is placed just ahead of the filling machine and run at the same speed. The can bodies are fed into a reformer which expands them to the cylindrical form, a second machine puts a flange on either end, while a third rolls on the bottom end and the completed can travels down a chute to receive its charge of salt and salmon at the filling machine.

This procedure can be used with lithographed cans or even with key–opening cans which have been scored entirely around the body near one end. The completed can is equal in every way to those which have not been collapsed.

INSPECTION AND WEIGHING

Some canneries use an automatic weighing machine at this point in the canning line. If the can contains the proper weight, the machine allows it to pass on, but if the can is underweight or grossly overweight it is side tracked. Inspectors then adjust these cans to the proper weight. These workers also trim off projecting bits of flesh, repack cans which show pieces of skin or bone on the top and generally do whatever they can to improve the appearance and uniformity of the pack.

EXHAUSTING AND SEALING

Until recently the standard method of "exhausting" to obtain a vacuum in the can, still used to some extent, was the steam "exhaust box." This apparatus by a series of chain belts, alternately traveling in opposite directions, shunted the cans from belt to belt and forced them to travel for more than 100 feet while in contact with the steam. The contents expanded and forced out most of the air. If the can was sealed while still hot a suitable partial vacuum was produced when the can was finally cooled after processing.

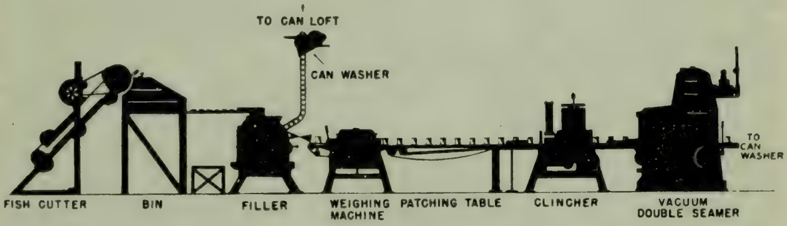


FIGURE 21.—Salmon canning; filling and closing the cans. (By O. E. Shostrom. Courtesy, Northwest Branch, National Canners Association.)

Where this method is still used, the cans pass through the exhaust box open or with the lids rolled on loosely. This loose seam is formed by the "clincher." Through such a loose seam the air can escape, while the "second operation" converts it into a tight and finished seam. The cans are "exhausted" at temperatures about 209° F. for a period averaging 10 minutes.

The steam box as a means of removing part of the air has been almost entirely displaced by the vacuum–closing machine (Fig. 21). This machine is essentially a large vacuum chamber, from which a part of the air is withdrawn by a powerful pump. The cans, with tops rolled on loosely, pass from the clincher into this chamber through pockets or ports in a carefully synchronized revolving, air tight valve. A portion of the air in the can is drawn out and the seam rolled tightly, after which the can leaves the chamber through another valve.

After the cans have been sealed, they pass along a belt through a washer which is essentially 2 perforated pipes which shoot jets of water under strong pressure on the cans, removing any bits of fish or other material from the can surface. The cans then roll down an incline, and are arranged mechanically or by hand in iron trays known as "coolers," which are placed 6, 10 or 12 deep according to the size of the can, on small trucks or cars. A cooler will hold 12 dozen No. 1 tall cans or twice that number of ½-pound flats.

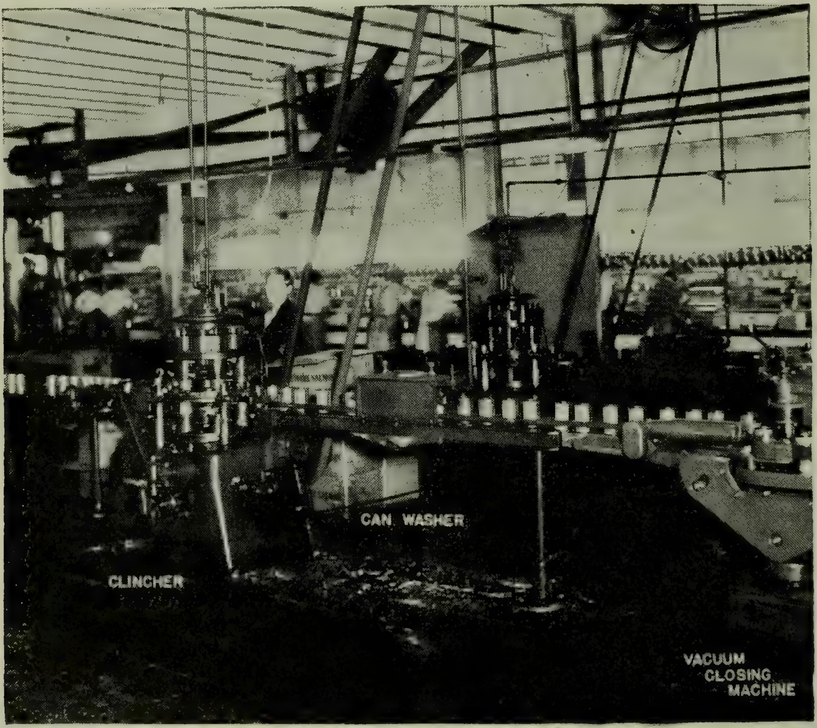


Figure 22.—Salmon canning line; clincher, can washer and closing machine. (Courtesy, Continental Can Company, Inc.)

PROCESSING, COOKING, OR "STERILIZING"

The truck loads or cars of salmon holding up to 864 tall cans, are shoved into retorts as soon as they are loaded. The retorts are large horizontal iron cylinders used for cooking the hermetically sealed cans under pressure. Retorts are constructed to hold 3, 4, 5 or 10 cars. As many as 11,000 cans are cooked at one time in an individual retort. Many retorts are equipped with automatic control devices to insure against faulty operation as to the temperature and time of cook.

When the retort door is tightly sealed, the steam is turned on but several vents are left open for a time in order that all the air within the retort may escape. At this time the thermometer should read about 212° F. and the pressure gauge about zero. The vents or valves are then gradually closed and the retort is brought up to processing temperature and maintained there for the duration of the desired cooking period. The thermometer and pressure gauge should be in agreement, that is, a temperature of 240° F. should correspond to a pressure of about 10 pounds. This is the temperature used generally except for a few companies which prefer one slightly higher.

After a period of about 90 minutes the steam is turned off and the valves gradually opened to allow the steam to escape and air to enter. When the pressure falls to zero the door may be opened and the can trucks pulled out. A few of the more recently constructed retorts have a door at each end with a slightly inclined internal track facilitating by gravity the filling and emptying of the retort and also simplifying the routing of the raw and cooked fish.

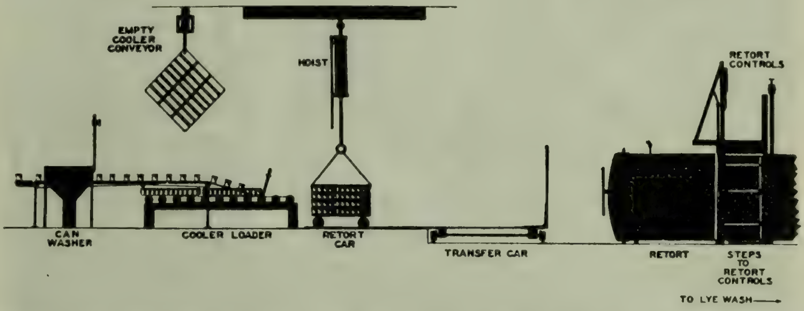


FIGURE 23.—Salmon canning; washing cans after sealing; loading cans and transferring to retort for cooking (retorting). (By O. E. Shostrom. Courtesy, Northwest Branch, National Canners Association.)

While 90 minutes is the standard processing time for the 1 pound can, other sizes containing from ¼ to 4 pounds require more or less time according to size. The cook for salmon was established partly on the basis of softening the bones to the point where they could be easily eaten. There used to be three divisions into which the process could be divided; the precook in the exhaust box by means of which the can entered the retort hot and reached a sterilizing temperature quickly, the main cook and the period of cooling during a portion of which the center of the can remained at the sterilizing temperature. The exhaust box has been almost eliminated and methods for more rapid cooling are contemplated. This will put the entire burden of sterilization upon the main cook, which may have to be increased. Processes now used for cans holding less than 1 pound are: ½ pound cans for 80 minutes and ¼ pound cans for 70 minutes at 240° F. (10 lbs. pressure). The processing used to date for "4 pound" (602x403) cans is 195 minutes at 242° F.

WASHING THE CANS

As the cans come from the retorts they may be greasy or dirty due to handling or the escape of oil from some of the cans during cooking. The trays (coolers) of cans, therefore, are passed through a weak alkaline washing solution known as the "lye wash" in which the can tops receive a scrubbing. At the same time the cans are carefully watched for signs of defective seams. Such cans will float or give off bubbles of air in the water. From the lye bath the cans pass to a fresh-water tank and sprays of fresh water remove all traces of lye which would damage the appearance of the cans if allowed to remain.

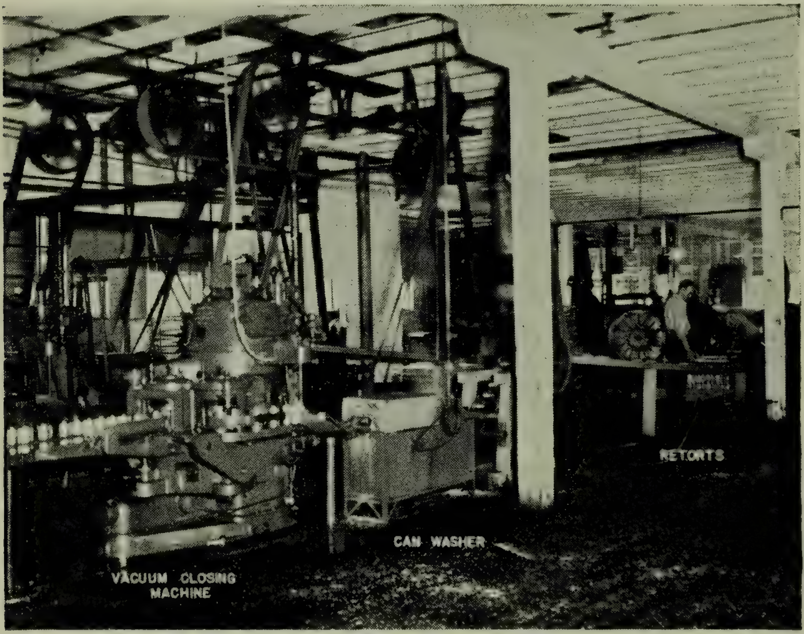


FIGURE 24.—Salmon canning line; closing machine, can washer, retorts. (Courtesy, Continental Can Company.)

Formerly, the washed cans were then taken to the warehouse and coolers spread out on the floor to remain until cool enough to case or stack. With increased speed of production, the space available for cooling has become inadequate and the cans are sometimes stacked while still too warm, which results in a prolonged cook of the salmon. A more rapid method of cooling has become not only desirable but imperative.

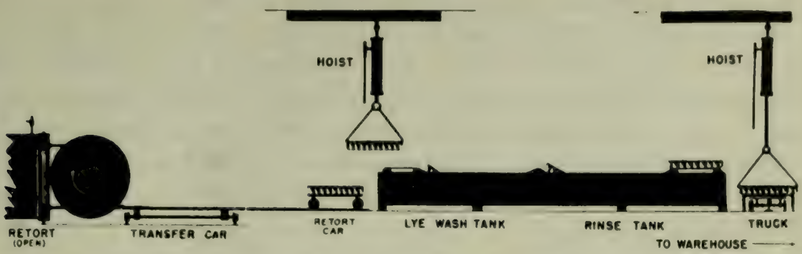


FIGURE 25.—Salmon canning; removing cans after retorting, washing cans, and transfer to warehouse. (By O. E. Shostrom. Courtesy, Northwest Branch, National Canners Association.)

LACQUERING

Rusting of cans has been a serious problem to canners from the first days of the industry. The first salmon cans were coated with red paint. Later variously colored lacquers were produced which dried rapidly. The cans were passed through a bath of the lacquer and dried by a hot air blast. The advantages of lacquering are offset by certain disadvantages such as higher cost, fire hazard and inconvenience. The practice has been almost though not entirely discontinued. Enameled tin plate for can ends and for a small percentage of can bodies has been substituted for lacquering. Some canners use only plain cans and under favorable conditions experience no difficulty.

LABELING

The first labels used were very crude, printed in one color on inferior paper and did not surround the can. About 1870 some Pacific Coast canners imported full-sized labels encircling the cans and printed in four or five colors with a variety of panels and grotesque designs. In recent years labels have been greatly improved, usually in the direction of simplicity and attractive design.

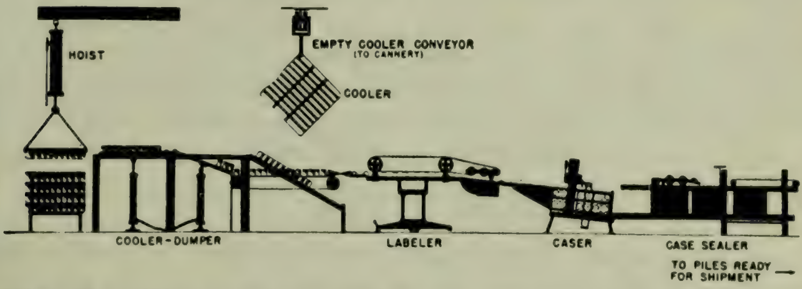


FIGURE 26.—Salmon canning; labeling and casing. (By O. E. Shostrom. Courtesy, Northwest Branch, National Canners Association.)

When canning operations are slack, some cans may be labeled at the cannery, but a larger proportion of the Alaskan pack is shipped unlabeled to warehouses in the United States for later labeling by warehousemen, jobbers or wholesalers. Labeling may be done by hand or by machine and surprisingly enough there is not much difference in cost. An experienced hand labeler can handle over 10,000 cans in an 8 hour day. While a machine will label about 5 times that number it requires several people for its operation. A great deal of research has been conducted on pastes, gums and label paper, and most of those in present use are very satisfactory.

BOXING OR CASING

Canned salmon formerly was shipped entirely in wooden boxes and a small percentage of the pack still reaches the market in that container. Fiberboard cartons have largely displaced the wooden box.

The standard "case" for statistical purposes consists of 48 1–lb. cans, 96 one–half pound cans, 192 one–quarter pound cans or 12 four–pound cans. The 1–pound cans are usually shipped 48 to the case but a few are marketed in cartons holding 24 or even 12 cans. The ½–pound cans are usually packed 48 to the carton but occasionally 24 and in Canada they are packed 96 cans to the case. The ¼–pound cans which are a specialty pack are usually attractively packaged in small cartons of 12 or 24 cans.

FLOATING CANNERIES

The original salmon cannery on the Pacific Coast was built on a scow in the Sacramento River in 1864, and, in a sense, may be called a floating cannery. In 1867 a crude counterpart was built on the Columbia River, also on a small scow measuring 50 by 20 feet. From that time until 1911 the salmon canning industry seems to have built its canneries on land or at least on piles extending out from the shore. In the latter year the old ship "Glory of the Seas" was fitted out as a cannery and became the prototype of all subsequent floating salmon canneries. From time to time new ships have been outfitted and have operated on Puget Sound, Southeastern, Central or Western Alaska. Some of the earlier ships have been discarded and others outfitted with more modern equipment until today the American industry has five or six floating canneries and their use seems to have become quite firmly established. The Japanese had two such vessels at least as early as 1932 and more have been added since. In fact their competition with the Japanese shore canneries became so severe that the Japanese government had to interfere and restrict their activities somewhat.

The elimination of the space–consuming steam exhaust–box, the development of large double–ended retorts, the use of the collapsed type of can completed as needed, and the improvement of all machines in the canning–line have all contributed to the compactness and speed of operation which make the floating cannery feasible. Increased speed of production and the almost complete adoption of the fiber carton have, however, increased the difficulties of adequate cooling of the cans before they are stored in the hold of the vessel.

The American floating canneries have all been remodeled from vessels previously devoted to other uses. Much ingenuity and skill have been displayed in the utilization of the necessarily limited space. The fish bins are usually placed on the upper deck from which the fish can descend by gravity to the iron chink and the cleaning tables and then enter the canning line proper. A recently outfitted floating cannery has fish bins and iron chink both fore and aft with a canning line extending along each side of the vessel terminating in large 10–car, double ended retorts.

The floating cannery has one advantage over the shore cannery in the ability to transport supplies and crew to and from the fishing location and to bring back a large part of pack. There is a considerable saving in passenger fares and freight charges. Repairs and changes in the machinery may be carried out during the winter to good advantage by bringing the cannery back to its home port.

Some liberty of action is possible with the floating cannery since it may be operated in more than one location during the year. However, a convenient shore location from which a sufficient supply of fresh water may be obtained, usually by tank scows, is essential. Lack of adequate space for cooling the cans has led to attempts at cooling by water. For this purpose fresh water must be used, necessitating strain upon the supply. The advantages of the floating cannery appear to be offset by its inherent disadvantages.

The five American floating canneries operating in 1938 packed some 216,000 cases mostly in the western part of Alaska. This constituted about 3.2 percent of the total Alaska pack and 3.0 percent of the total United States pack for that year.

CANNED SALMON INSPECTION

Many canners open cans from their pack at frequent intervals throughout the packing season in order to detect and correct any imperfections or faulty practices before much harm is done. The completed pack is subject to the examination of the State and Federal inspectors, who by their watchfulness and criticism have done much to improve the pack. A very large percentage of the annual production is made in Alaska and upon shipment to the Pacific Coast States is immediately in interstate commerce and subject to federal inspection. Moreover this portion of the pack is handled at a few ports, which permits centralized inspection and control.

In addition to governmental inspection the industry has voluntarily supported its own inspection service carried out by the National Canners Association. Nearly all of the Alaskan pack and much of that produced in Oregon and Washington is examined by the Association. This examination is concerned not only with the condition of the fish from the standpoint of freshness but also with workmanship and quality. Every defect is pointed out to the packer in order that changes in the process of manufacture may be made and the product improved. A separate report is made to the packer on each code packed and at the end of the season a tabulated report on the entire pack is submitted which may be compared with a similar report covering all of the pack inspected by the Association.

A generous number of sample cans is drawn for examination and if a single objectionable can is found, from 48 to 96 additional cans are drawn from the code involved and another examination is made. The packer is invited to be present at any of these examinations and particularly at re-examinations in order that any objectionable condition may be pointed out and changes in cannery practice may be recommended. The value of government and association inspection is clearly apparent in the steadily decreasing number of objectionable cans found in the pack. Few food products are as thoroughly examined as canned salmon.

TABLE 11.—*Description of different species of Pacific salmon and of steelhead trout after canning*

Species (Scientific and common name)	Color of oil	Color of flesh	Texture of flesh	Size of flakes	Size of vertebrae	Size of scales
Oncorhynchus nerka (red salmon)	Deep red	Deep red	Very firm	Small, thin	Small	Medium
Oncorhynchus tschawytscha (chinook salmon)	Deep red through orange to almost white	Bright-red to white	Soft	Large, thick	Large	Large
Oncorhynchus kisutch (medium red salmon)	Light red to yellowish pink	Light red with orange shade	Rather firm	Large to medium, thick	Large	Large
Oncorhynchus gorbuscha (pink salmon)	Deep pink to light yellow	Pink	Tendency to be soft	Small, thin	Small	Small
Oncorhynchus keta (chum salmon)	Light pink with orange shade to yellow	Light pink	Firm	Medium	Medium	Medium
Salmo gairdnerii (steelhead trout)	Light orange to yellow	Pink with orange shade	Rather soft	Large, thick	Large	Large

SARDINES

The sardine-canning industry of the United States is located in Maine and California. In Maine the small herring (*Clupea harengus*) is the basis of the industry, while in California the pilchard (*Sardinia caerulea*) is used.

According to Food Inspection Decision No. 64 of the United States Food and Drug Administration, any small clupeoid fish may be canned as sardines, but the word "sardine" on the label of the can should be accompanied with the name of the country or State in which the fish are taken and prepared. Anchovies are considered misbranded if labeled as sardines, because they are not classified as clupeoid fishes according to this decision.

MAINE SARDINES

FISHING AREA AND SEASON

The sardine-canning industry of the Atlantic Coast of North America is located in the State of Maine, and the adjacent Canadian Provinces of New Brunswick and Nova Scotia. The raw material used is the "sea" herring (*Clupea harengus*). Herring are taken off the Atlantic Coast as far south as Delaware Bay, but only in the above localities are the abundance of the catch and the size of fish such that canning operations are commercially practicable.

Herring travel together in large schools, and at certain seasons of the year are found in shallow water near shore, usually migrating over a more or less regular route and feeding on the plankton which is most abundant in these waters at the time. The fishing season commences about the middle of April and may extend to the first week of December, but most canneries cease packing before that time. During the latter part of the season the larger sizes of herring predominate which are not as desirable for canning as the smaller; a dependable supply is not available, and often the fish must be transported a greater distance. The length of the canning season is also governed by the probable market for the pack. The peak of the season is from about the middle of July to the first of September.

SECURING RAW MATERIAL

Herring are caught in two types of gear: (1) Weirs, which are enclosures or traps of a primitive type, located so as to block the line of travel in the feeding migration of the herring along the shore, and (2) stop nets used together with purse seines, a more modern type of apparatus, with advantages over the weir in certain localities.

WEIRS

The older type of weir was very crudely constructed, with a framework of light poles driven into the bottom, sometimes supported by stones, with tree branches or brushwood woven in between the poles. More recently, heavy tarred cotton webbing has been used instead of brush.

A weir consists of two sections, first a "lead" or fence extending from shore and crossing the path of migration, terminating in a "heart" or oval enclosure. In some locations an opening is left at one side where the lead joins the heart, but in other places, where the fish may come in from both up and down the coast, the heart may be entered from either side of the lead.

Blocked by the lead, the herring try to find a way around and are led into the heart. Hook-shaped extensions into the base of the heart prevent the fish from again finding the opening, so they are held until they can be removed. A boat then enters, blocking the entrance with a piece of netting and concentrates the herring into a small space within a seine which is first laid out so as to take in most of the area within the heart and is then gradually hauled together forming a "bag." The fish are dipped from the bag into boats, which transport them to the cannery.

Weirs are used today along the Maine coast from Eastport to Rockland principally because strong tides and the nature of the shore make the use of nets difficult, but sardine canners in other areas of the coast have abandoned the weir and now use stop nets, together with purse seines in catching sardine herring. The stop nets are 100 fathoms long by 5 to 7 fathoms deep and ordinarily have a 1-inch mesh, stretched measure. Several "shots" or lengths of net usually are required to surround a school of fish. The nets commonly are made of 14-6 hawser-laid cotton twine, with a 5-inch border, top and bottom, made of heavier twine, and are tarred from time to time to preserve them. They are taken up two-fifths in hanging; that is, the length and depth are reduced by this proportion so that the net will not hang as a straight wall, but will "bag," making it more difficult for fish to escape.

SEINES

Nights during the "dark of the moon" in the summer and early fall, are considered best for seining sardine herring, as they come in shore to feed at that time. A small boat is sent out scouting in the evening for signs of herring—distinguishable only by an experienced "looker." Some of the indications of herring are: Silvery flashes in the water, flecks of foam on the waves, flocks of gulls hovering and swooping, the presence of large predatory fish such as dogfish, and the "flipping" sound made by the herring as they "play" on the surface. This also causes flecks of foam on the waves. Days or even weeks may pass without the observation of signs of a school of herring.

When sardine herring are found the seine–boat captain determines the direction in which they are moving and makes an estimate of the size and probable number of the fish. This is very necessary, for if the fish are too large for canning, or if the school is small, time spent in catching them would be wasted. The herring are scouted until they reach a place where they can be trapped, usually a cove, or in the lee of a point of land, with a depth of water not exceeding 6 fathoms (36 feet) at high tide.

The seine–boat crew "makes one end of the seine fast to the shore, and leaves the balance of the seine necessary for the set in the dories. Then a small power boat is tied on to the dories and the seine is quickly towed out, imprisoning the fish, this power setting seldom takes over five minutes. The actual catching of the fish, however, is the smallest part of the labor, for from the time the fish are caught until they are loaded in the boat to be taken to the factory, there must always be someone watching them to see that they do not escape. The fish are usually caught at high tide, and about 6 hours later the seine, which has been stretched in a straight line from one headland to another across a small bay or inlet, must be worked around into a circle or pocket and this is where the real labor begins. * * * As soon as the pocket is made, it is necessary to put anchors and kegs out to keep the seine from collapsing and smothering the fish." (Bastow, 1938.)

The captain notifies the cannery when the herring are safely pocketed, giving the location and an estimate of the catch and size of the fish. The herring usually are held in the pocket at least 24 hours, because they are sometimes full of "feed" when caught. After 24 hours the digestive tract is empty and the fish are not as susceptible to enzymic deterioration on the way to the cannery. In addition the fish are "wild" and difficult to handle immediately after being pocketed in the stop net. If necessary, the fish can be held alive in the stop nets for 2 weeks in calm weather.

TRANSPORTING AND RECEIVING

When the cannery requires raw material, "carrying" or "run" boats owned by the cannery are sent to the spot where the stop net is pocketed. The carrier boats have a capacity of 40 to 60 tons of fish, usually loading and making the run to the cannery at night so that the cannery need not wait for fish during the day. It is also cooler at night and there is no possibility of the sunlight adversely affecting the fish. Some fishermen may contract to deliver all of their fish to a single cannery for a period of several months, while others sell each catch to the highest bidder (Socony–Vacuum Oil Co., 1937).

When the carrying boat arrives at the stop net, a purse seine about 40 fathoms long by 6 fathoms deep is run inside the pocket. When enough fish have been surrounded, draw lines at the bottom of the seine are pulled so that the bottom is puckered together like an old fashioned bag–purse and the fish cannot escape. One side of the seine is made fast to the rail of the carrying boat and the fish are concentrated in the "bunt" or center portion by pulling the "wings" or sides of the seine into the seine boats. A power-operated dip net holding from 3 to 5 bushels is dropped into the churning mass of fish, then hoisted above the deck. The dip net is emptied by releasing a draw–string at the bottom. The first fish are examined to see if they are of satisfactory quality and free from "feed."

The carriers or collecting boats should have the fish hold divided into sections and only a shallow layer of fish should be loaded into each section. The distance from the fishing area to the cannery varies from less than one-half mile to a maximum of about 100 miles. Fish are usually brought in from the further limits, only at the end of the season when cooler weather permits arrival in good condition. No ice is used, because it would bruise the small herring, but if they cannot be landed within a very short time, salt is scattered on the herring as they are loaded into the hold. From 200 to 500 pounds of salt, or an average of 280 pounds, are used per hogshead of fish, which weighs about 1,200 pounds.

A large bucket holding approximately 500 pounds is used to unload the fish at the cannery. Each bucket is tallied without weighing, as holding a certain amount. A flume extends from the unloading point to storage bins, where the fish are held for a short time until used. The herring are brined in these bins if they have not been salted in the boat. The fish are carried along the flumes by a stream of water that both washes them and removes the scales and excess salt.

GRADING THE RAW HERRING

The fish must be small to be suitable for canning. Fish fully developed in size do not make a product of satisfactory quality in this type of pack because the flavor is too strong, the texture too coarse, and the loss in packing too great. Herring canned as sardines vary in size from 4 to 10 inches. When taken for canning, they should have a fairly high oil content and should be free from "feed." The fish are graded on these factors.

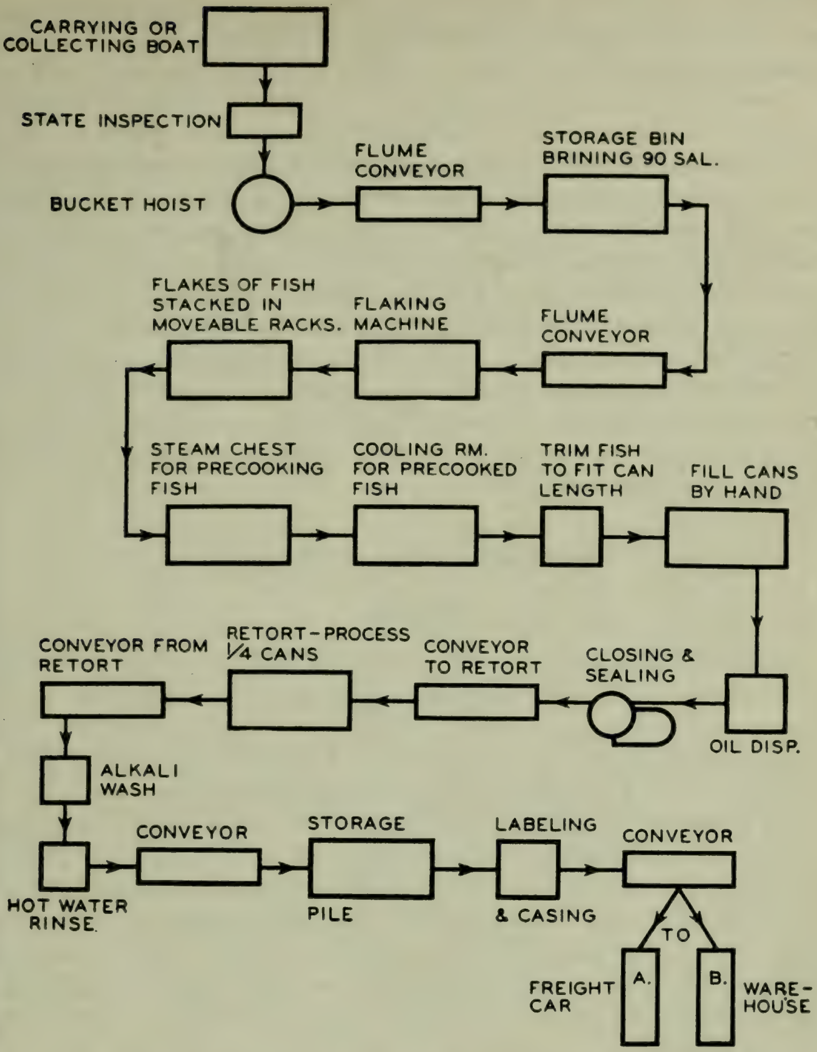


FIGURE 27.—Flow sheet of Maine sardine canning.

DRESSING OR CLEANING

Formerly the herring were dressed immediately after landing, principally to prevent any possible damage from fish containing feed, as immediate dressing inhibits loss through enzymic spoilage. This also has the advantage of reducing the amount of waste handled in preparing the fish for canning.

Only one large firm now dresses the fish as the first step and then only in certain packs. A few small canneries still dress the fish by hand before preparation for the can. Most canners dress and trim the fish in a single operation, as they are filled into the cans. This is done when there are no indications of "feed" in the digestive tract.

If fish are dressed raw they are unloaded on tables. Workers stationed at either side of the dressing table seize three or four fish with the left hand, cutting off their heads in a single movement with a knife or with shears designed for the purpose. They then pull upward and outward in a second and almost simultaneous movement as the cut is completed, which removes most of the viscera with the head. The dressed fish are dropped into pans at the worker's side, while the offal is shoved through openings in the table into buckets or barrels. Both the cut fish and the offal are taken away from the dressing table at regular intervals. Unnecessary waste and poor workmanship are guarded against through periodic inspection of the dressing operation by the foreman and the State inspector.

PREPARING FOR THE CAN

BRINING

If the fish have not been salted when loaded into the boat, which is the usual practice, brining is the first step in preparation. The fish are salted or brined for two reasons, in addition to preserving the catch until it can be handled: (1) To flavor the canned product, and (2) to improve the texture, making the flesh firmer and not so liable to crumble in handling. The fish are brined in the tanks used for holding the raw material after landing. These are watertight bins made of wood and the usual dimensions of an individual tank are 5 feet long by 3 feet wide and 3 feet deep. Each tank holds from 45 to 50 bushels of fish, and a cannery installs a set of 6 tanks so that sufficient fish for a normal run may be landed at one time, making it unnecessary to hold fish in boats at the dock.

The brine is a very heavy salt solution, testing from 90° to 100° salinometer. Fresh potable water is used in making the brine but little attention is paid to the purity of the salt, although it is possible for chemical impurities in the salt to affect adversely the flavor of the product. The time required in brining averages 2 hours and varies from 20 minutes to 3 hours, depending on the size of the fish, whether they are whole, the degree of fatness, and the atmospheric conditions.

When the fish have absorbed sufficient salt they are drained and rinsed in fresh water. Sufficiency of brining is determined by appearance of the skin, which should not be wrinkled as that indicates overbrining, and by the degree of firmness, which is judged through pressure with the fingers. The percentage of salt absorbed by the fish varies. If the fish are small a total salt content of from 2.5 to 3.5 percent is considered best in the canned product.

FLAKING

The fish are conveyed by flume and an endless slat–belt conveyor to the "flaking machine" on the second floor. Empty flakes are fed into the machine receiving a thin layer of fish from the conveyor and are then stacked in racks. The flakes are rimless trays, made with a framework of heavy iron wire, about one–quarter inch in diameter and are covered with quarter–inch–mesh wire screen. Some flakes are from 18 to 22 inches wide and about 3 feet long. Others are 30 inches square. The racks, which are equipped with small wheels, hold from 25 to 50 flakes each, with 28 as a customary average.

In the earlier days of the sardine industry, flaking was done by hand, and great pains were taken to see that no two fish touched. This is no longer considered necessary, the only requirement being that the fish must not be heaped but spread out in a thin layer. A flake will hold from about 100 to 125 herring, depending on size of fish and flake.

PRECOOKING

Precooking is required to produce the desired sardine flavor.

Steaming — The most widely used method of precooking is steaming. It is the cheapest method of preparation but it is admitted that the flavor and texture of the product could be improved. In the steam–cooking process, the filled racks are wheeled from the flaking machine to steam chambers at one end of the packing room. These chambers are oblong steam boxes, large enough to admit four racks and equipped with tightly fitting doors. Dry steam is admitted to the steam chamber at 100 pounds pressure. A blow–off valve of the chamber is left open to permit rapid steam circulation without building up a pressure. The fish are steamed from 8 to 20 minutes, depending on their size.

The racks are then moved into a long room, usually equipped with a blower fan and heating coils or with other mechanical apparatus for creating a current of dry, warm air, in which the steamed fish are cooled and the surface moisture is removed. This requires from 30 minutes to 2 hours, the length of time depending on the size of the room, size and amount of fish and efficiency of the apparatus. If the sardines are packed while still warm, most of them are broken into unusable fragments or the skin is loosened and they do not pack well in the cans. A temperature of 160° F. is considered the optimum for a drying room.

Frying—In Maine, all precooking formerly consisted of frying in an oil bath and this method is still used to some extent. Under favorable conditions, frying resulted in an excellent product with a moisture content of about 65 percent, which is an optimum for canned fishery products. The moisture content in fish cooked by steaming is somewhat higher. The principal objection to frying is the high cost of oil. It is also necessary to change the oil at frequent intervals or the pack will acquire "off–flavors." The cooking oil becomes oxidized if it is used repeatedly over too long a period of time. The use of the oil bath is confined to a few plants today, generally for fancy–grade packs.

If the fry bath method is used, the racks are taken from the flaking machine directly to a drying room, where the fish are dried in a current of heated air at temperatures about 100° F. for about 2 hours or until the surface of the fish shows no indication of moisture. There is a loss in weight of about 12 percent in this drying procedure.

Frying takes place in shallow metal tanks with a closed steam coil set about halfway down. Although publications on canning state that the "fry bath" is filled with water to a level just below the steam coil with a top layer of oil for frying, Maine sardine canneries no longer use water. The reasons given for the use of water were to reduce the cost and so that waste could be drawn off through a valve in the bottom of the tank eliminating the necessity of draining the whole tank and filtering the oil. It has been found that a better–grade product is obtained if oil only is used.

The tank is filled with approximately 15 barrels of vegetable oil, usually winter–pressed cottonseed oil. The oil is changed frequently. The flakes of dried fish are passed by conveyor through the oil bath, which is heated to a temperature of about 230° F. at a rate which should insure that the fish are cooked sufficiently when they emerge.

The adequacy of cooking may be determined by breaking the tail fin of a cooked fish. It it snaps off and is brittle, the fish are done, but if the tail does not break cleanly, the cooking is not sufficient. The frying time varies from 4 to 6 minutes, depending on the size and condition of the fish. After frying, the flakes are again stacked in racks which are taken to the drying room, where the fish are dried and the oil drained off in a current of heated air from 1 to 2 hours.

One packer uses a method developed by Beard (1926) which consists essentially of drying and cooking the herring in a single operation by forcing blasts of hot air over the brined and flaked fish in an apparatus of the tunnel–dryer type. The time required averages 15 minutes, with some variation depending on the size and condition of the raw material. This method is said to dry the fish more evenly and the moisture content is more easily controlled.

FILLING

When the fish are cool, the racks are wheeled to the end of the filling table. The first or older style of filling table arrangement consists of a long open framework about 5 feet high, supporting a double conveyor belt. Small tables with a worker on each side are set at right angles on both sides of the conveyor. A cannery packing a maximum of 2,500 cases per day will have about 60 packing tables and employ 120 hand packers to fill the cans. Women and girls are employed as packers. The flakes are transferred from the racks to the conveyor belt and are removed by the packers as needed. Each packer has a metal tray of empty cans.

Filling the cans requires considerable skill. Approximately the same number of equally sized fish must be packed in each can. They must be laid in so that only the silvery skin will show on opening the can, and in a firmly–packed layer since loosely–packed fish are liable to break. The cans are usually filled with sardines laid in longitudinally, with heads toward the ends of the can and tails over-lapping in the middle. In packing the larger fish the heads and tails are alternated to make an even layer. Very small fish are "cross packed," that is, laid in parallel with the ends of the can. The smallest sizes require especially careful handling.

More than 90 percent of the sardines canned in Maine are packed in the one–quarter size can which contains from 4 to 15 fish in the standard grades. Special packs may contain as many as 30 small fish. From 6 to 10 flakes of fish are required to fill each case of 100 one–quarter cans. Fish packing 11 or 12 to the one–quarter size can are considered the most desirable size.

The packers clip off the heads with a pair of shears, or if the fish have been dressed raw, trim off enough to fit them to the can. If the fish are small, only the heads are removed, if they are medium sized, both head and tail ends will be clipped; of the largest fish, only the tail portion is used. The loss in trimming varies from 15 to as much as 60 percent of the original weight. The average packer in Maine will pack about two cases per hour, but speed depends on the size of the fish.[8]

If the fish are small, 10 to 12 to the can, the yield per bushel, about 70 pounds, is from 1 to 3 cases of 100 quarter–size cans, while if they are larger, 4 to 5 to the can, from 0.8 to 1.5 cases may be expected. The most generally accepted estimate of yield is 20 cases per hogshead if the fish are small.

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[8] National Recovery Administration. 1934. Hearing on the code of fair prices and competition. New England canning industry, p. 181. Washington.

As each packer fills a tray of cans, it is removed by a workman who substitutes a tray of empty cans, carrying the full tray to a short conveyor feeding into the machine where the cans are filled with oil or sauce. Filling is paid for on a piece–work basis with the present rate of payment varying from 15 to 18 cents per case.

The second variety of filling table is a type widely used in hand filling other varieties of canned foods. It consists of a long table with a conveyor in the middle about 2 or 3 feet above the working level. The packers work in long rows down each side of the table. The flakes of fish travel on the top conveyor belt, while each can as it is filled is placed on the return conveyor running flush with the top of the table, to be carried immediately to the oiling and can–sealing machines. This arrangement apparently is more efficient than the first one described.

By far the greatest part of the pack is put up as "oil" sardines. Winter–pressed cottonseed oil customarily is used. Some fancy grades are packed in imported olive oil. Corn oil formerly was used to some extent but Maine sardines are rarely, if ever, packed in corn oil at present.

Two types of machines are used to add oil to the cans. In the first type, trays of 20 or 25 cans are oiled simultaneously. In machines of the second type, as each can passes through the filling machine it trips a lever, sending a jet of oil into the can. The oil is heated to 180° F. Oil is sometimes added to the cans before filling but this practice is being abandoned as it makes packing very messy, the canned product will not contain a uniform amount of oil and the loss through wastage is greater. The amount of oil used is set by law in the State of Maine at a minimum of 4 pounds per case, for the so-called "standard" pack, and at 5 pounds per case for "extra standard" and "fancy" grades.

Mustard sauce is sometimes used instead of oil, usually with fish of the larger sizes running from 4 to 5 to the one–quarter size can, or lots which may show rough handling. Tomato sauce is used in a few thousand cases of special pack Maine sardines. Some sardines are packed in a special spiced oil, made by adding oil of cloves or other essential oils of spices to cottonseed oil. A delicate spicy flavor is secured in the product, one relished in certain markets. Great care must be used in making up the spiced oil, as an excess of spice flavor will make the sardines almost inedible. A few small lots are also packed on special order with a spiced vinegar sauce; olive oil, pimiento and bay leaves; butter and bay leaves, or in other special "sauces."

EXHAUSTING AND SEALING

No heat exhaust or other method of obtaining a vacuum is used because of the heated oil used in filling. This is supposed to produce a sufficient vacuum. The filled cans are conveyed to a can seamer of the same type used in sealing corned beef or other "square" cans. These machines operate at a speed of 40 to 60 cans per minute.

In some canneries the cans drop from the sealing machine into large baskets made of perforated sheet metal which are lifted by hoists and carried to the retorts by an overhead trolley or are transported on low four–wheeled trucks. These methods rapidly are becoming obsolete, and have been abandoned by the larger canneries. Most of them now employ a belt–conveyor running from the can sealers directly to chutes into the retorts. Battering or distorting of the cans through falling is prevented by having the retort partially filled with water, which has a cushioning effect. When the retort is loaded with cans any water not displaced is blown out by steam. One canner uses retorts fitted with "fish-tail" chutes inside, along which the cans glide without becoming damaged.

Most of the retorts used in processing Maine sardines are of the vertical type and have a capacity of from 65 to 120 cases. The packers who use conveyor systems in filling the retorts have modified the usual type of vertical retort, narrowing the top to a small opening about 1 foot in diameter. There also is a small door in the side near the base of the retort, 1½ by 1 foot, through which the cans drop onto a conveyor when processing is completed. Recording–chart thermometers are quite generally used and one cannery has installed retorts fitted with full automatic control.

Under the automatic control system at the end of the processing period, steam is turned off and sufficient compressed air to maintain the pressure is admitted. An automatically controlled valve admits cooling water until the temperature within the retort is about 100° F. This procedure permits more accurate control of processing, cools the cans more rapidly, reduces the possibility of over–cooking and also the amount of washing necessary to clean the cans after processing.

PROCESSING

A few packers still use the hot-water bath for processing. However, these packers are subject to occasional losses through swells caused by under–processing.

When cooked in a pressure retort, the process varies from 30 minutes at 240° F. (10 lbs. pressure) to 90 minutes at 220° F. (3 lbs. pressure). There is at present no agreement as to sufficiency of process although research laboratories recommend 45 minutes at 240° F. If an open hot water bath cook is used, the process for one-quarter size cans is from 90 to 120 minutes.

COOLING AND WASHING

When the cans are removed from the retort, they are rinsed in an alkaline cleaning solution, then in fresh hot water and are left in piles until cool and dry enough for labeling and casing. In a few of the older plants, shallow wooden tanks may be used for cleaning and washing. If this is the case, the cans are contained in the metal crates or baskets in which they were processed and the baskets are dipped into the tanks. In the more up-to-date plants the cans drop individually from the retort onto a conveyor, passing through the cleaning solution, then through sprays of hot water under pressure.

Sardine cans require thorough cleaning, as they are covered with a thin film of oil as they come from the retort or cooker. The method of cleaning formerly employed was to put the cans in a drum containing sawdust, tumbling the cans until the sawdust absorbed a portion of the oil, then wiping the cans after they had been removed from the drum. This method is rarely if ever used today.

LABELING AND STORAGE

The cans are usually labeled and cased within a day or two after packing although this depends to some extent on the degree of activity in packing. The women who fill the sardines into the cans also pack the cans in cases and perform some of the labor in labeling. Therefore, when possible, this portion of the operations is left for times when the packers would otherwise be idle. This policy aids in giving more continuous employment to the cannery crew.

The label may be embossed in the top of the can previous to use by stamping the lid with a die. Each can may then be placed in an individual pasteboard carton or cased without any additional label. Some cans are wrapped entirely in heavy paper by machine, with the label printed on that portion of the paper covering the lid. Some lots are wrapped in light paper of the semi-transparent or tissue type and a label is pasted over the paper on the top of the can by hand. Lithographed cans, with the label enameled on the can lid, are probably most widely used.

The cans are cased by hand in fiberboard cartons measuring 15½ by 9 by 8½ inches and holding 100 quarter–size cans (Fig. 28). The gross weight of a case of quarters is approximately 36 lbs. Certain canners do not use the standard case, but market one holding 96 quarters and also sell smaller cartons holding 24 quarters. Three-quarter cans with net contents of approximately 11 oz. are cased in cartons of 48 cans. This size can is now used entirely for "mustard" sardines and the amount packed in 1938 was 47,160 cases or 4 percent of the total (Fiedler, 1939). Sardines were formerly packed in "one-half" cans, but this size of container has not been used for several years.

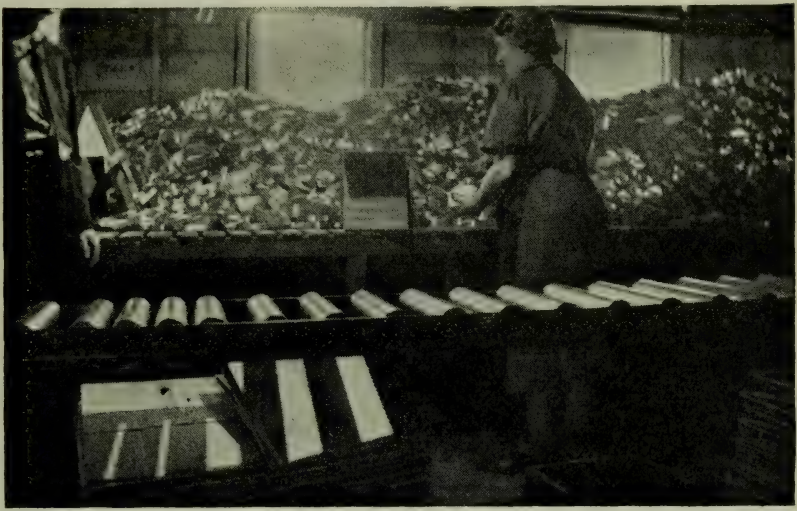

FIGURE 28.—Maine sardine canning; packing "quarter–oil" cans in cases.

Some packers do not store their pack; as soon as the cans are labeled and cased, they travel by conveyor directly into a railroad car on a siding outside the cannery door. A carload of sardines is 1,000 cases. The producer rarely holds the pack more than a few months. Every effort is made to dispose of the pack before the opening of the next season. This is not due to possible deterioration but the packing costs and selling prices fluctuate from year to year and as the packers generally operate on a narrow margin of profit, holding the pack in storage over too long a period may turn a small potential profit into a large actual loss.

INSPECTION

The sardine canneries of Maine are subject to a system of inspection administered by the Department of Agriculture of that State. The inspection system provides that an inspector shall be stationed in each cannery during the packing season, to examine all fish received before they are landed and to determine whether they are fit for use. If 5 percent or more of the herring show the presence of "red feed" the inspector condemns the catch. It is also his duty to see that sanitary packing conditions are maintained and that the workmanship in packing is not careless.

The regulations specify the quality of cottonseed oil in which most of the sardines are packed. If cottonseed oil is used the law requires that it be "winter-pressed" oil. Samples are taken by the inspector from each lot of oil delivered at the cannery and these are analyzed by the state to prevent the substitution of inferior oils. The inspection system seems to be working quite satisfactorily and it has resulted in raising the quality of Maine sardines.

In contrast to the regulations for canning sardines in California, processing times and temperatures are not specified, nor is it necessary for the retorts to be equipped with recording chart thermometers and control instruments. Official grades have not been promulgated though a step has been taken in this direction in the regulation requiring a minimum of 4 fish in any "keyless" one-quarter and at least 5 in key-opening cans.

PACIFIC COAST SARDINE CANNING[9]

FISHING AREA AND SEASON

The sardine canning industry of the Pacific Coast utilizes as raw material the California sardine *(Sardinia caerulea)*, which is closely related to the species canned as sardine in France, Portugal, and Spain. It is known as pilchard in the British Empire. The range of this fish on the Pacific Coast extends from Vancouver Island south to the Gulf of Lower California. The canning industry is centered at San Diego, San Pedro, Monterey and in San Francisco Bay, Calif. While the fish are taken in quantity off Coos Bay, Columbia River, and Grays Harbor area of the Oregon-Washington coast, they are utilized almost entirely for reduction purposes. Some are canned in Astoria, Oregon, and a small quantity is canned in 1 pound tall cans in British Columbia as pilchards. With these exceptions, the sardine canning industry is located in California. The fishing area covers a radius of approximately 150 miles around each port.

The season when sardines may be taken for canning or reduction purposes varies with the respective areas and is based on the time of year when they are in prime condition. At present, sardines may be taken for packing from August 1 to February 15 in the northern California or the San Francisco and Monterey areas, and in the San Pedro-San Diego district from November 1 to March 30th inclusive.

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[9] This section prepared by O. W. Lang, George William Hooper Foundation, University of California and N. D. Jarvis.

FISHING GEAR AND METHODS

The sardine purse seiners follow the general lines of the purse seine vessels of the North Pacific but are usually larger and heavier, with carrying capacities up to a maximum of 160 tons. The maximum load is taken only in calm weather and when short distances from the cannery make it possible to carry a deck load.

The fishing gear first used with any great degree of success was the lampara net, introduced by Capt. Peter Ferranti of Monterey (Campbell, 1938). This net was used almost exclusively from 1905 to 1929, but is now almost although not entirely obsolete. It was followed by the "half-ring" and "ring" nets. The ring net is still important in fishing for sardines. However, the purse seine is now used most widely and approximately three-fourths of the catch is made with this net.

The typical lampara net is 170 fathoms long by 20 fathoms deep. The central portion of the net to a length of about 40 fathoms is made of strong, fine meshed twine and forms a bag for holding the sardines. The sections on either side of the bag are of larger mesh and made of finer twine, and are known as the wings. The webbing is "gathered" to a point at the ends of the wings.

The "half-ring" net is a lampara net with purse rings and a purse line along the lead line of the central section or about two-fifths of the net which forms a bag for holding the sardines. Gradually additional rings were added, until they extended to approximately two-thirds of the lead line, after which it was called the ring net (Fry, 1931). The method of fishing is the same as for the lampara net, except that the bottom of the bag portion can be closed more surely and with greater speed than the lampara net.

The sardine purse seine is from 200 to 250 fathoms long and 20 to 30 fathoms deep. The lower part of the net does not taper toward the ends. The mesh size is the same throughout, however, the size of the twine varies from heavy in the strip along the cork line, to fine in the section along the lead line. The purse seine may be either tarred or bark tanned. Tanned nets are lighter and easier to handle than tarred nets but require more frequent preservative treatments. The lead line is more heavily leaded than the lampara net. At intervals of about 6 feet, iron rings known as "purse rings" are attached to the lead line and the purse line passes through the rings. The total weight of a sardine purse seine will range from 2 to 4 tons (Tribby, 1936).

As a rule, in California sardines are seined only at night during the "dark of the moon" although they may be caught occasionally on moonlight nights and sometimes even in daytime. The schools of sardines are located by the phosphorescent areas produced by their movements near the surface of the water. From Oregon to

British Columbia day fishing is the rule. The method of purse seining does not differ greatly from that used in the Pacific salmon fishery.

TRANSPORTING AND UNLOADING

The sardines, if used for canning, arrive at the cannery 1 to 8 hours after capture. The Bureau of Cannery Inspection, California State Health Department, requires that fish canned from any boat load must be packed within 12 hours after the arrival of the fishing vessel. An exception is made if the fish are to be canned as "quarter oils."

The cannery inspector stationed at each cannery examines the sardines as they are unloaded for the presence of bruised, broken, soft, sunburned or otherwise unsuitable raw material. The condition of the fish is checked against the time and locality of catch as given in the captain's log. If the poor condition of the fish is thought to be due to over-loading, the supervising inspector of the district may limit the tonnage to be carried by the offending vessel. The packer decides whether the fish are to be used for canning or reduction purposes, unless the inspector finds that the load, or any portion, is unfit for canning. If the inspector decides that the fish are unsuitable for either canning or reduction he may terminate the unloading and order rejection of the balance.

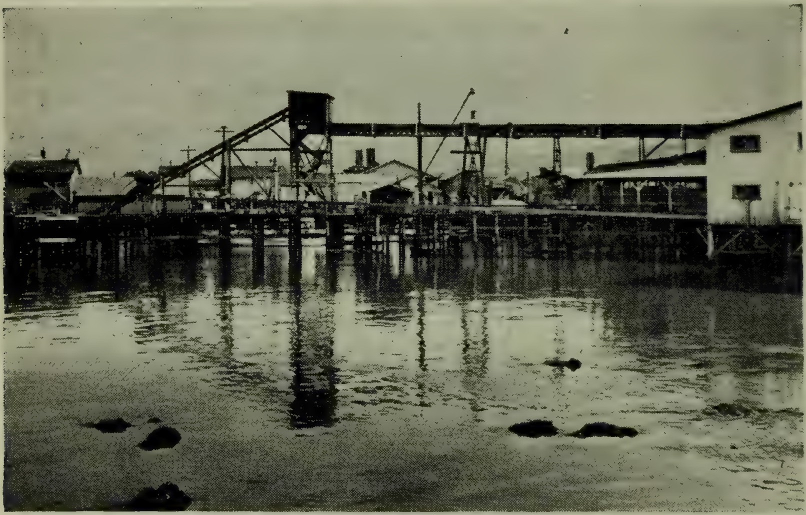

FIGURE 29.—Elevator and conveyor at a sardine cannery, Monterey, California.

Variations in type of water front and contour of shore line have made it necessary to adopt different methods for unloading in each packing center. The canneries in the San Pedro district are separated from the unloading dock by a street running along the water front. Here the sardines, after being brailed from the boat into a hopper, are elevated about 30 feet (Fig. 30) and are then discharged into weighing buckets holding approximately 750 pounds. When a bucket is full, the weight is registered automatically by recording scales and the fish are emptied into a flume or onto a conveyor running at a slight decline into the cannery across the street. A stream of water transports the fish into the receiving tanks. The scaling machine or squirrel-cage washer is almost obsolete.

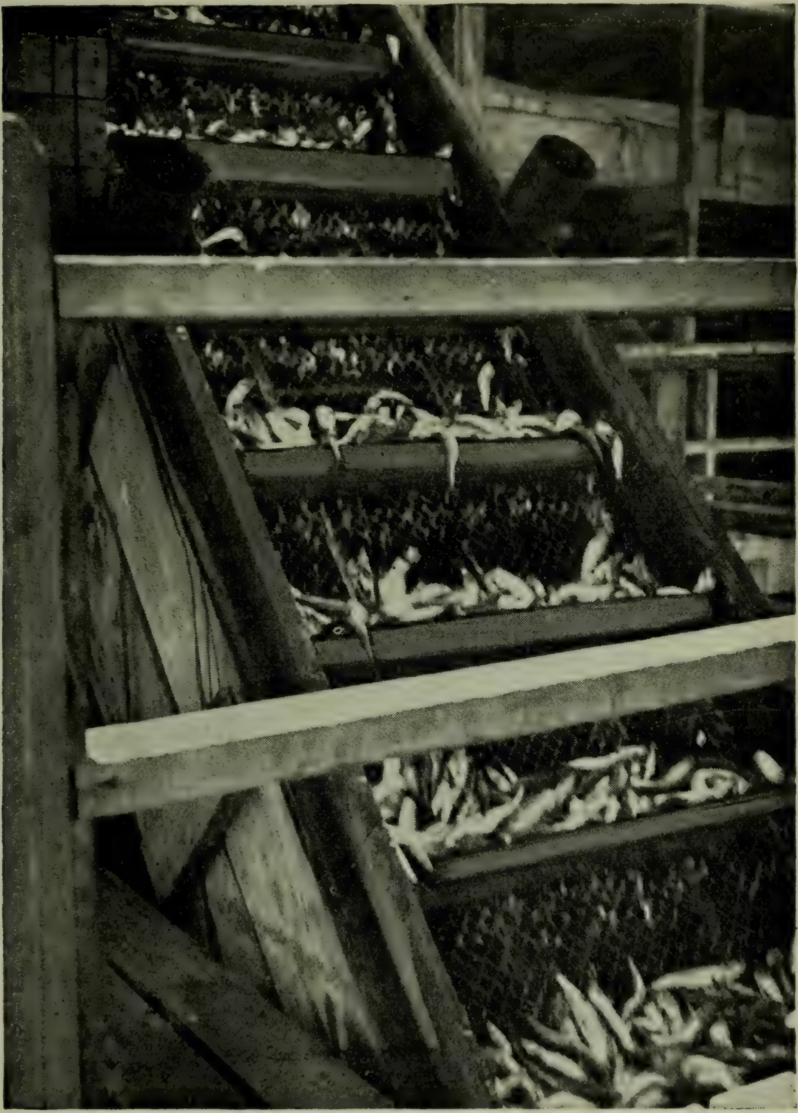

FIGURE 30.—Elevator from unloading pump to automatic scales at a sardine cannery, Monterey, California.

At Monterey an 8-inch pipe extends along the bottom of the bay from the cannery to a point approximately 150 yards offshore and opens into a rectangular hopper at the surface of the bay. Spaces are left between the boards forming the sides of the hopper so that water flows in and out. The purse seine boat ties alongside the hopper into which the fish are brailed. Fish and water are sucked into the cannery by a powerful pump. The high velocity at which the fish are transported by this method serves to wash and scale the sardines very effectively. On receipt at the cannery, they are weighed as described in the preceding paragraph and flumed to the receiving tanks. The sardines are usually allowed to remain here until a sufficient supply has accumulated to permit canning operations without interruption. The general custom is to unload for approximately one hour before starting the packing operations.

DRESSING AND WASHING

A sliding door near the base of the receiving tank is lifted and fish are permitted to flow as needed onto a table or trough connected with the cutting machine. The sardines are fed by hand, head first and backs up, into a deeply slotted conveyor belt, the slots being just wide enough to hold the bodies of the fish. The sardines are carried past a revolving circular blade, which severs the backbone and cuts the head almost off but leaves it attached to a thin strip of belly flesh. The conveyor then passes a whirling paddle or revolving brush which completes the heading operation, pulling out the entrails attached to the head, with a strip of belly flesh.

Two other slightly different types of machine are in use. In one the circular blade is adjusted so that the head is cut off squarely and completely. The fish then passes a vacuum apparatus which removes the viscera by suction. In the other machine, the head is completely removed and a revolving burr is plunged into the body cavity, reaming out the viscera. This burr is perforated and during the time it is operating, water at high pressure is forced out the end, flushing the body cavity.

California sardines are no longer cut by hand, with the exception of small fish to be packed in quarter-oil cans. Unlike Maine sardines in the small size container, small California sardines are headed and cleaned before, not after pre–cooking.

The cleaned fish drop from the conveyor into an iron box at the end of the cutting machine. When the box is full a checker trips a lever which releases the contents into a flume. This box holds approximately 25 pounds of fish. He then punches a card hanging by the machine feeder, as cutting is a piece-work operation. If the sardines are not to be packed in 1- or ½-pound ovals, other machines may be attached to the end of the packing table which cut the sardines into container–length pieces, or this operation may be performed when the fish are cleaned and headed. Fluming the cut fish causes less damage to the flesh than other conveyor systems and also washes off the blood.

PREPARING FOR THE CAN

Methods described for handling, cutting and conveying the sardines are essentially the same in all packing plants. From this point on, however, the operations vary materially and where such standard procedures as brining and drying were universally employed at one time, they are now used only for the oil fry or raw vacuum style of packs.

BRINING

The cleaned and eviscerated fish are flumed to the brining tanks. After being filled with fish, the flume water is drained and a dense salt solution of 80° to 100° salinometer is added. Brining requires from 60 to 90 minutes. Mechanical agitation or intermittent stirring by an attendant is necessary during this time if the salting is to be uniform. Brining makes the texture more firm, extracts the blood, removes slime which adheres to the fish even after washing, and provides a means of temporary storage, so that the sardines may be held in good condition.

DRYING

The purpose of drying is to extract sufficient surface moisture so that during the ensuing oil fry the skin will not become ruptured and peel. The brined fish are flumed to a wire mesh conveyor leading to a tunnel-shaped tumbler drier. These driers are usually 50 to 75 feet long, 7 to 9 feet wide and 10 to 14 feet high, containing 6 to 8 endless wire mesh belt conveyors, with alternate runs, staggered and traveling opposite directions. The sardines are conveyed to the top run and after traveling the length of the drier they drop 6 to 8 inches directly below to the staggered conveyor which is moving in the opposite direction. This process is repeated until the sardines are discharged to a conveyor which transports them to the fry vats or to the next step in the canning operation.

A current of warm dry air is blown through the drier taking up moisture. The moisture–laden air escapes through air ducts or the open end of the drier. The time of drying varies with drier construction, velocity and temperature of the air and condition of the fish, with the latter factor perhaps the most important.

When sardines are properly dried, the loss in weight is from 4 to 6 percent at a drying time varying from 60 to 90 minutes at 90° to 100° F.

OIL FRY

The standard pre-treatment method was formerly the oil fry; while it is seldom used, it is not obsolete and is demanded in certain markets. Essentially it is the same as the fry cook formerly used in packing Maine sardines and probably originated from this source. The fry troughs are built on the same plan as those used on the Atlantic coast, but are wider and longer, averaging 70 feet in length. The tank is filled with water to a level of 2 to 3 inches below the steam coil and above this level with destearinated sardine oil. Cottonseed oil or occasionally peanut oil was formerly used. However, since large quantities of oil were required which could not be reclaimed for other purposes, it was finally displaced in favor of the natural sardine oil which serves the same purpose and is reclaimed at little expense. Sardine oil is never used for frying more than once.

To speed up handling and to economize on floor space, the drier and fry vats are usually placed parallel and in close proximity to each other. A short conveyor carries the sardines from the drier to a point where the fry baskets are filled and placed in the fry vat. The discharge end of the fry vat leads directly to the cooling platform. A thin layer of fish is placed in baskets with dimensions of 36 by 18 by 4 inches. A basket 18 inches square and 4 inches deep is also used. An endless chain conveyor transports the baskets through the fry vat. The vat temperature at the beginning of the fry is usually 180° to 200° F. while the final temperature approximates 230° F. Large "pound oval" sardines are sufficiently cooked in 7 minutes while the smaller fish packed in "quarter oil" cans require about 5 minutes. Cooking is judged sufficient when the meat is free from blood and the backbone may be separated readily from the flesh. The baskets on emerging from the cooker are stacked on movable racks and placed on the cooling platform to drain.

The sardines are cooled from 12 to 15 hours, depending on atmospheric conditions. Fifteen ounces of cooked fish are packed in 1-pound oval or 7 ounces in ½-pound oval cans. Other can sizes or shapes are not used in the fry pack method. An open steam exhaust from 12 to 15 minutes at 210° F. follows packing. The steam condensate and the oil rendered from the sardines are removed by an automatic draining device in which the cans are slowly inverted and then righted. This is followed by saucing and sealing operations.

RAW VACUUM PACK

Approximately 1 ounce of tomato or mustard sauce is added to each empty 1-pound oval can. The cans are conveyed to the packing tables where they are filled with 15 ounces of brined and dried raw fish. An additional ounce of sauce is added as the packed cans pass to the vacuum sealing machines. The covers are loosely clinched and the cans conveyed through the rotary valve into the vacuum sealing chamber where a vacuum ranging from 18 to 22 inches is drawn during the sealing operation. An internal vacuum from 3 to 5 inches is thus secured in the filled cans. The packing procedure is simple, efficient and the cost is low. One disadvantage may be cited, namely, a tendency toward loose and slack filled containers.

BROILED PACK

Approximately 16 ounces of raw cleaned sardines are packed into 1 pound oval cans. The filled containers travel for 45 minutes through hot air ovens with temperature ranging from 320° at the beginning to 350° F. at completion of the cook. The heat source is a fire box connected directly to the oven very much like one constructed for a high pressure boiler. The fuel is either oil or gas and the flames are thermostatically controlled. A high velocity fan assures an even temperature distribution. When broiling is completed the cans are drained, sauced and sealed.

PRECOOK PACKS

The various methods of precooking now used for the greater portion of the California pack of 1-pound oval sardines result in products differing markedly from either the oil fry, the oven broiled or raw vacuum packs. The majority of these methods involve prolonged heat treatments in continuous steam exhaust boxes after the cans are packed (Fig. 31). All steps in the canning procedures must be continuous from the time the sardines are first delivered until they are canned.

The exhaust treatment or precook may be interspersed with one or more draining operations following which the cans may be subjected to dry hot air or superheated steam to overcome excess moisture in the final canned product. All precook methods are modifications of the fry pack. Longer exhaust periods eliminated the costly frying procedure and the time necessary to cool the sardines so that they might be packed without crumbling. It was also found that drying and to some extent brining could be eliminated since the flesh became moisture-laden in precooking and a considerable amount of salt absorbed through brining was lost when the cans were drained.

In the precook packs, 16 ounces of raw cleaned fish are filled in 1-pound oval cans. The cans must be overfilled in order to avoid a slack fill since a shrinkage of 1 to 2 ounces occurs during precooking and draining. The cans then pass to various types of continuous steam exhaust boxes where they are precooked from 30 to 45 minutes at 210° F. This is followed by draining after which the cans are sauced and sealed. In certain canneries the condensate, moisture and oil cooked out of the fish may be eliminated by one or two draining operations during the cook, later followed by a final draining.

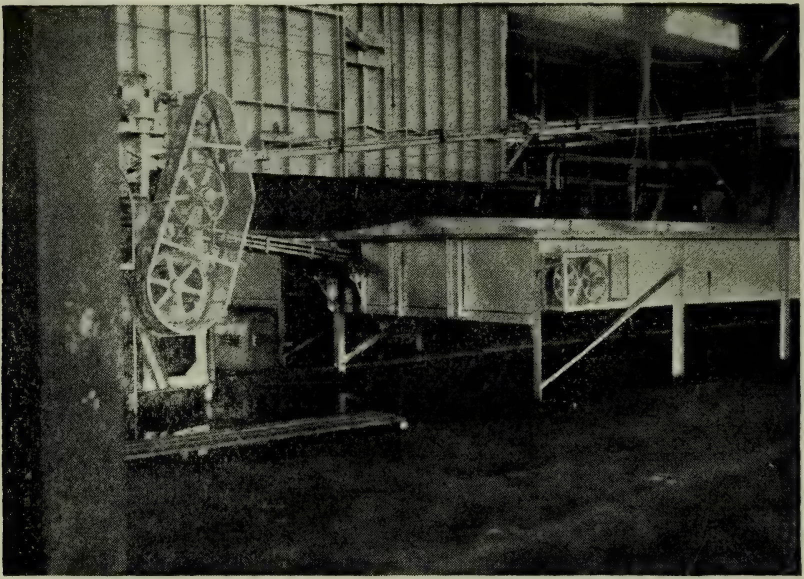

FIGURE 31.—Steam exhaust type of precooker, California sardine cannery.

A second style of precook consists of a 20- to 25-minute steam exhaust at 210° F. following which the cans are drained and given another cook in super heated steam at temperatures of 220° to 230° F. In a third type of precook the cans pass through a vertical steam exhaust box containing a series of gas jets at the bottom. The cans require approximately 35 minutes for completion of the cook. The temperatures secured in different sections of the box are variable and range from 220° to 240° F.

DRAINING

Several draining mechanisms are in use. One consists of a series of oval plates the size of a 1-pound oval can lid, on a revolving chain conveyor, in which the plates are timed to meet and grip the cans as they emerge from the exhaust box. A can drained in this machine completes a 360° revolution in a relatively short time. Another draining mechanism consists of an endless chain conveyor suspended on two pulleys. A second chain conveyor surrounds the inner conveyor. It is spaced by angle–iron supports with sufficient clearance to permit the cans to travel in between the conveyors. The cans enter the drainer, which may be 6 to 15 feet long, and travel its lower circumference in an inverted position. Added draining is also secured as the cans are inverted and then righted on the circular portions of the pulleys.

FILLING WITH SAUCE

The precooked and drained cans pass under a saucing device which adds 2 ounces of tomato or mustard sauce to the 1-pound oval can and 1 ounce to the ½-pound oval or the 9-ounce rectangular can. The saucing mechanism usually consists of a quick acting gate valve above the conveyor in which the orifice is calibrated to deliver the proper amount of sauce. In another type of machine a small reservoir holds the amount of sauce to be delivered. The cans trip a lever as they travel along the conveyor and the sauce is released. Tomato sauce is usually heated to 150° F. while mustard sauce is added cold since heating causes coagulation and separation of the mustard.

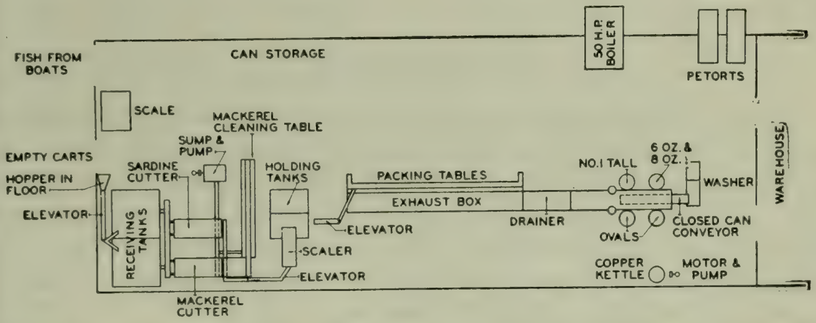

FIGURE 32.—Floor plan showing equipment layout of a California sardine and mackerel cannery. (Courtesy, Standard Steel Corporation.)

SPECIALTY PACKS

SARDINES IN BRINE

This pack consists of fish which have been cleaned and packed into cans, followed by a long exhaust or precook, with a hot brine added just prior to closure. Other pre–treatment methods may include smoking but in any method of preparation the fish are seldom thoroughly cooked before brining and closing. Two sizes of cylindrical cans are used, the 6-ounce paste (202 x 309) and the No. 1 tall (301 x 411). The 6-ounce paste can is packed with smaller cuts of fish to a fill weight of 5 ounces. The No. 1 tall can is better adapted to the larger sizes but may be and is used for the smaller cuts as well. The fill weight in this can is 17 ounces of cleaned raw fish. The exhaust time for the 6-ounce can is approximately 5 minutes while for the No. 1 tall, 20 to 35 minutes at 210° F. is necessary to produce the desired shrinkage. A circular plunger attached, directly to the closing machine and slightly smaller in diameter than the can, depresses the can contents to secure the necessary head-space. A hot 4-percent salt solution is then added and the cans are sealed.

SARDINES IN OIL

Small sardines are cleaned, brined and dried, then fried in oil as previously described. These fish, having little or no natural fat, tend to absorb the oil from the fry bath. After cooling sufficiently so that they will not crumble in filling, 3½ ounces of fish are packed in the ¼ pound (404 x 300½ x 014) can and from 7¾ to 8 ounces in the ½ pound (410 x 307½ x 103) key open cans. After an exhaust of approximately 7 minutes at 210° F. the cans are drained, and ¾ to 1 ounce of cottonseed or olive oil is added to the ¼-pound can and 1½ ounces of oil to the ½-pound can. The cans are then sealed and processed.

SARDINE FILLETS

Sardine fillets may be packed in oil, smoked, in a sweet spiced sauce or "natural." For this pack the sardines must be large, mature, firm of flesh and in prime condition. The increased popularity of fillet packs has prompted the design of rather unique filleting machines although in the past this operation was performed by hand. If cut by machine the whole sardines are placed ventral side up into grooved depressions of a conveyor. A circular blade completely severs the head and on passing the blade a timed finger removes the cut fish toward 2 circular blades which separate the flanks or fillets.

Another type of filleting machine consists of 2 belts arranged in a "V" shape into which the sardines are placed ventral side up as previously mentioned. The whole sardines are firmly held between the 2 belts and are carried to 2 circular blades which remove the fillets. The fillets then travel by flume to either brining or holding tanks.

The fillets may or may not be brined, depending on the packer. If the canning operation includes brining, the fillets are immersed in a 20- to 22-percent salt solution for approximately 30 minutes.

They are then packed in 9-ounce (300 x 404 x 108) rectangular machine-drawn cans, to an approximate net weight of 7 ounces. The fillets are placed in 2 layers separated by "30-pound" vegetable parchment liner with 6 to 8 fillets per can. Packing is followed by an exhaust of 20 minutes at 210° F. and after draining, the cans are sealed. If the fillets are not brined, dry salt is added prior to sealing. Various types of sauce may also be added.

SMOKED FILLETS

There are two procedures for packing smoked or "kippered" sardines. In the first method the whole fish are brined from 60 to 90 minutes in a 20-percent salt solution. The fillets are then cut and arranged on flakes or wire trays 18 inches wide by 24 inches long. These flakes are then placed on a conveyor which carries them into a vertical type continuous smoke house, in which the smoke is evenly distributed by a blower. The fuel is California oak smothered in tan bark, the smoke house temperature varies from 100° to 110° F. Smoking requires approximately 90 minutes and after a short cooling period the trays are taken directly to packing tables where the fillets are placed in 9-ounce rectangular cans. An exhaust of 20 minutes at 210° F. then follows. The cans are drained and either cottonseed or olive oil, tomato sauce or a sweet spiced sauce is added before sealing.

In a second method the fillets are brined for approximately 30 minutes in a 20-percent salt solution containing garlic and other condiments. They are then carried into a tunnel-shaped continuous smoke house equipped with a blower which distributes the smoke. The smoke is produced by burning oak wood or manzanita roots. After packing in 9-oz. rectangular cans the containers are conveyed through a continuous gas heated oven for approximately 20 minutes. A sauce is then added and the can is sealed.

SMOKED SARDINES IN TOMATO SAUCE

After evisceration the sardines are brined in a 20-percent salt solution for approximately 45 minutes. They are then smoked, packed in 9 oz. rectangular cans, sauced and sealed.

SEALING

All cans are sealed in automatic closing machines (Fig. 33). Oval and rectangular cans require a special type of seal. An attachment to the sealer embosses a code onto each can cover identifying the canner, packing date, style of pack and retort batch.

WASHING

The sealed cans are conveyed from the sealing machine into the can washer. The washed cans fall into perforated retort baskets or crates which are usually constructed to fit the contour of the retort. No attempt is made to stack the cans since it has been found that sterilization is more uniform when the cans are piled loosely in the baskets. From the standpoint of efficiency of sterilization, stacked cans correspond to a continuous cylinder divided by a series of baffle plates, which in this instance are the can covers or ends. A cylinder of this type, therefore, becomes more difficult to sterilize.

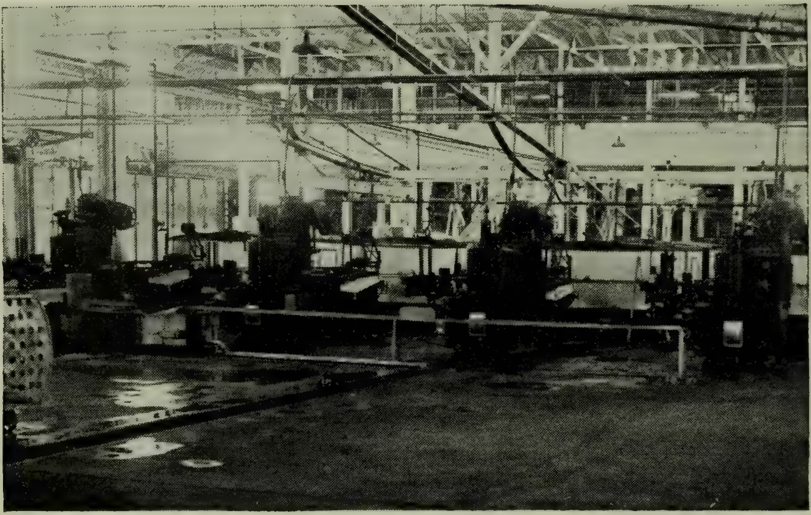

FIGURE 33.—Battery of can sealing machines, California sardine cannery.

PROCESSING

The crates are rolled into horizontal retorts equipped with recording chart thermometers and other equipment required under regulations of the California Bureau of Cannery Inspection (State of California, 1935). The processing times specified by the Bureau of Cannery Inspection are as follows:

Type pack	Can size	Initial temperature (° F.)	Processing time in minutes at 230° F.	Processing time in minutes at 240° F.	Processing time in minutes at 250° F.
Brine	6 oz. paste	70	100	55	40
	6 oz. paste	130	95	50	35
	6 oz. paste	150	95	50	30
Brine	No. 1 picnic	70	115	75	60
	No. 1 picnic	130	105	70	50
	No. 1 picnic	150	100	65	50
Brine	No. 1 tall	70	125	90	75
	No. 1 tall	130	110	80	65
	No. 1 tall	150	100	75	60
Brine	No. 10	70	------	------	------
	No. 10	130	------	------	------
	No. 10	150	------	240	210
Oil	"quarter"	------	75	30	15
Oil	"half"	------	90	45	25
Mustard or tomato sauce	½-lb. oval	70	110	55	40
	½-lb. oval	130	105	50	30
Mustard or tomato sauce	½-lb. oval	150	100	50	30
	1-lb. oval	70	130	75	55
	1-lb. oval	130	120	70	50
	1-lb. oval	150	115	65	50
Filleted sardines with "30 lb." parchment separating layer	9-oz. rectangular	70	130	75	55

INSPECTION AND EXAMINATION

In California a State inspector of the Bureau of Cannery Inspection is stationed at each cannery. It is his duty to inspect the raw material prior to canning and to remove representative sample cans from each code packed during the day. These are later examined at the field laboratory of the inspection service. No pack is released into the channels of trade until the requirements of this Service have been met. The examination includes a determination of freshness of the raw material, the presence of bruised fish, "honeycombing," "green feed," and adulterations such as entrails. No attempt is made to establish grades although particular attention is directed toward the workmanship in packing and the suitability of the raw materials. The odor is determined as in the examination of salmon. Data concerning the cutting report of the laboratory may be obtained from table No. 12.

A complete production record is maintained by each packing plant. The recording thermometer charts together with the production record are examined by the inspector. This examination covers the retort process time and the temperature. The number of cases and cans incorporated in each batch code must correspond to the production record as well as to the notations on the recording thermometer chart. The production record as well as the recording thermometer chart must also show the full process time at the respective sterilization temperature and equivalent pressure. When all of these requirements have been met the inspector releases the day's pack for shipment. If any defect is observed a "restraining order" is issued prohibiting shipment of the pack until the defect has been corrected or official instructions are issued for final disposal after laboratory examination. Inspectors are especially instructed to apply restraining orders to packs that show any of the following defects: (1) Heavy cut-out weights; (2) defective temperature curves; (3) any visible spoilage noted in the warehouse; and (4) on any code or codes where there is any question concerning the suitability of the pack for human consumption.

TABLE 12.—*Cutting sheet used in inspection of canneries in California.*

STATE DEPARTMENT OF PUBLIC HEALTH
Bureau of Cannery Inspection

DAILY CUTTING REPORT
SARDINES

CANNER:__________________ DATE OF CUTTING______________

LOCATION:________________ DATE OF PACK_________________

NOTE: List each can separately

Code	Size can	No. fish	Honey-comb	Bruised	Sauce	Texture	Color	Green feed	En-trails

REMARKS AND OPINION ________________________Inspector

________________________Clerk

TUNA[10]

SPECIES CANNED

Tuna canned in California is produced from four species within the mackerel family *(Scombridae)*. Another species of this group, the bonito, is canned tuna style, but may not be labeled as tuna, nor may the yellowtail, which belong to the family of jacks *(Carangidae)*. The different tuna in order of commercial importance are:

YELLOWFIN *(Neothunnus macropterus)*

The yellowfin tuna may be distinguished by the rather long pectoral fin, reaching or almost reaching the front of the anal fin but not past it, as in the albacore. The series of 8 or 9 finlets following the second dorsal and anal fins and the tail, show a yellowish tint, giving the species its name. The color of the body is dark blue on the back and upper sides, shading into iron gray below. The State of California has set legal size limits beyond which this species may not be landed, with a minimum of 7.5 pounds and a maximum of 150 pounds. The yellowfin may reach weights of 300 to 400 pounds, but these larger fish are very scarce. The average size of the yellowfin is about 30 pounds. The season extends over most of the year. It ranges from along the Pacific coast of North and South America from southern California to northern Chile.

BLUEFIN *(Thunnus thynnus)*

Next in importance from standpoint of volume of pack is the bluefin, which is the largest of the tunas. It is also known as the "horse mackerel" or "leaping tuna" and is said to be the same species as the European tuna. Its distinguishing features are that the pectoral fin is shorter than the head, the second dorsal is sharper than that of the yellowfin, and the finlets and tail fin are bluish in color. The color of the back is deep blue, shading into iron gray on the sides and silvery below. The sides may show many small silver spots, while the freshly caught fish exhibits an iridescent sheen. The maximum legal size limit is 150 pounds, but it may attain a weight of over 250 pounds (Walford, 1931). The average size is approximately 30 pounds. It is found on the coast of Southern California and Northern Mexico from June through November.

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[10] This section prepared by O. W. Lang, Geo. Williams Hooper Foundation, University of California and N. D. Jarvis.

SKIPJACK *(Katsuwonus pelamis)*

The skipjack, which is also known as the "striped tuna" is the smallest of the tunas. Its principal distinguishing characteristics are the 4 or 5 dark stripes which extend horizontally along the lower side of the body. The tail has a low keel on each side and the body is scaleless with the exception of a few large closely adhering scales in the region of the pectoral fin. The color of the body is bright blue above, becoming dull after the fish dies, shading into silver along the sides and below, with the stripes as above described. Skipjack range in weight from about 3 to 20 pounds but it is illegal under California law to land fish weighing less than 4 pounds. It is caught off the coast of southern California from August through November but is landed from clippers fishing off Mexico, Central and South America, at other seasons of the year.

ALBACORE *(Germo alalunga)*

The albacore was the first species of tuna canned in California. It is the only one that may be labeled as white meat tuna. It formerly was considered the choicest tuna, but now the fancy packs of yellowfin and bluefin tuna are considered by many to be equal in quality. The albacore pack was greater than that of all other tuna combined until 1925, when the run suddenly declined to a small fraction of the former size. The distribution of the albacore is from Puget Sound to Lower California, and occasionally southward. It also is found off Japan and Hawaii. It was formerly thought that only occasional stray specimens wandered north of Southern California, but since 1937 large catches of albacore have been made off the Oregon and Washington coasts where it is the basis of an important fishery and canning industry.

While the albacore may reach a maximum weight of 80 pounds, the average commercial specimen weighs approximately 25 pounds. The peak of the season in California is June to August and in Oregon it is August and September. The chief distinguishing characteristic is the great length of the pectoral fins which reach some distance past the front of the anal fin. The secondary common name of "long–finned tuna" has been given to it on this account. The color of the albacore is dark steel-blue above, shading into dull silver below.

BONITO *(Sarda chiliensis)*

The bonito has a flesh somewhat darker and more strongly flavored than the four species of tuna just listed. It resembles the tunas generally but the body is more slender. The pectoral fins are short and a series of finlets extending from the second dorsal fin and the anal fin are each 6 to 8 in number, while the tail has a fleshy keel on each side. The body is striped obliquely or horizontally above the lateral line with narrow blackish stripes. The color is blue above with greenish reflections and a metallic luster, shading into a silvery hue below. The bonito has a range extending from the coast of Oregon southward along the coast of South America, and is also found off the Hawaiian Islands. It is caught throughout the year but is most abundant in the summer months. The bonito reaches a maximum length of some 30 inches and a weight of 20 pounds but the average weight is given as approximately 8 pounds.

YELLOWTAIL *(Seriola dorsalis)*

The yellowtail has a range extending from Point Conception on the coast of California, southward to the Galapagos Islands, but the California fish and game laws do not permit the canning of yellowtail taken off the coast of that State. Yellowtail is canned to some extent, utilizing fish caught off the coast of Mexico. The distinguishing characteristics are: Two dorsal fins, the first being composed of spines; the second of soft rays, and the two are practically in contact. The longest spines of the first dorsal fin are less than half the height of the first soft rays and there is a blunt, low keel on each side of the caudal peduncle. The color is bright metallic blue above, becoming silvery on the sides and below; and a yellowish brown horizontal band extends along the side of the body from the eye to the tail (Walford, 1931).

The yellowtail is found in the summer months from Mazatlan and Cape San Lucas on the coast of Mexico, north to Santa Barbara, California. It reaches a length of 3 feet and an average weight of 20 pounds.

MISCELLANEOUS

Frozen albacore and frozen oriental tuna *(Thunnus orientalis)*, which is the species taken in greatest quantity off the coast of Japan, are imported for canning purposes. The tuna canned in New England has the common name of "horse mackerel" and is classified as *Thunnus thynnus*, differing but slightly from the bluefin tuna of the Pacific coast.

FISHING AREAS

The area fished by the southern California tuna fleet reaches from the coast of southern California to and slightly beyond the equator extending from the continental mainland to points approximately 800 miles off shore and includes areas around practically all the islands within these general limits, including the Revilla Gigado Islands, Clipperton Island, Cocos Island and the Galapagos Islands.

The large "bait fishing" vessels forming the high–seas tuna fleet, which fish for skipjack and yellowfin, bring in from 60 to 70 percent of the total catch and work the fishing grounds as follows: In the winter months, or from November to the end of February, the fleet is found off the Galapagos Islands. The boats then fish off the mainland coast of Central America through March, April, and May. In June and July they may fish in the Gulf of California or around Cape San Lucas. In August and September the fleet covers the lower California coastal area with the neighboring banks and islands as far as Clipperton Island. In the fall months they mostly return to the mainland coast of Central America. While this is the general procedure, the judgment and experience of the individual captain as to fishing conditions in the various known areas and advance information on the availability of bait, or presence of fish, are the principal factors governing exploitation of the fishing grounds.

The albacore fishing area off the coasts of Oregon and Washington is such a recent development that it is not yet definitely established. Commercial landings have been reported to date from British Columbia to southern Oregon. Catches have been made as close as 5 miles from shore and as far distant as 50 miles. Searches for fish have been made in the area from 50 to 200 miles off shore but so far have not been productive.

FISHING CRAFT

A special type of craft, the "tuna clipper," has been evolved in the live bait fishery for tuna, and was described in detail by Godsil (1938). These vessels range from 65 to 145 feet in length. The hull has the same general appearance as that of a destroyer of the World-War I period with a high bow or raised forecastle deck, except that the tuna clipper is wider in beam and does not narrow sharply toward the stern. In place of the depth charge racks of the destroyer, large bait tanks are erected on deck aft and are used to carry the live sardines or anchovettas essential as bait or "chum". These tanks are supplied with a constantly circulating flow of water by large pumps which lift seawater through an 8 to 10 inch suction inlet on the bottom of the hull.

The deck above the fish hold is sheathed with 3-inch cork insulation. This insulation may be continued down the sides to the turn of the bilge and ceiled over with planking. It is not usual to insulate the hold below the turn of the bilge. These vessels are driven by diesel engines with a maximum of 600 horsepower. The holds are refrigerated to prevent the ice from melting rapidly, but the fish are usually not frozen, unless they are in close proximity to the coils of ammonia pipes. The direct expansion ammonia system is the customary type of refrigeration. A tuna clipper requires a refrigeration capacity of up to 40 tons.

Purse–seine boats fishing for tuna are of the same type as those engaged in the herring, mackerel, salmon or sardine fisheries. This fishery requires a large sized boat with considerable cruising range so that the existing purse seine fleet has not been especially satisfactory for use in tuna fishing. The first seiner designed especially for tuna fishing was built in 1937. This craft was built on the general lines of other purse seiners but has a length of 121 feet, is made of steel and is fitted with refrigeration compressors, a complete sea-water refrigeration system and other special equipment.

Salmon-trolling boats are used in fishing albacore off the Oregon and Washington coasts. These are described in detail in the discussion of salmon canning.

FISHING METHODS

In the Oregon albacore fishery "jigs" or artificial lures of the type evolved during the early days of the California tuna fishery are employed. The fish are taken in much the same method as are salmon by trolling, so that the salmon trollers have taken readily to fishing for albacore. The bone, rag, or feather jigs are towed about 100 feet astern of the fishing boats operated at speeds of from 4 to 7 knots.

In the live bait fishery the method is as follows: When the fishing grounds are reached, lookouts are stationed to watch for signs of tuna. The presence of a school of fish is detected by tuna leaping clear of the water. When near but not breaking the surface, their presence is indicated by a dark ruffled spot which may be seen at a considerable distance on a clear day. At other times the presence of a school of fish may be revealed at great distance by a flocking of birds working overhead since the tuna in pursuit of food will drive their quarry to the surface. The seabirds hover overhead following the school, swooping down when the opportunity serves to pounce upon what food they can secure. Thus to the tuna fisherman "working birds" invariably mean fish (Godsil, 1938). The tuna in their search for food drive smaller fish and squid to the surface where they are consumed by porpoise which follow the tuna so that the presence of a school of porpoise is a sign of tuna.

When a school of tuna is found they are attracted to the sides of the vessel with live bait, dipped from the bait tank and scattered over the water by a "chummer." His special duty is to "chum" the tuna to the side of the fishing craft and he is responsible for the condition of the live bait, keeping the tanks cleaned, and in good repair; feeding the bait, and so far as possible, keeping it in good condition.

If the tuna are biting they dart savagely at the live bait, causing a swirl at the surface of the water known as a "break." The fishermen clamber out on racks hanging outboard and around the stern, almost at water level. The racks are made of steel rods, and are approximately 6 feet in length by 3 feet in width. Each rack has a knee rest on its outer side some 18 inches above the floor. The fishermen are equipped with heavy bamboo poles about 8 or 9 feet long with a 3 foot length of heavy cotton line fastened to a loop of strong linen at the end of the pole. A 2-foot leader of No. 18 to 22 piano wire is fastened to the end of the cotton line in such a manner that it can be removed easily and quickly changed for another.

Lures are preferred to fishing with bait as the fish are taken more rapidly and easily. The typical lure consists of a barbless hook fixed in a tubular piece of brass filled with lead, with feathers partially concealing the hook. This is known as a "squid" or "striker." The feathers are encased in an animal parchment to prevent damage when fish strike the hook. When water-soaked, the lure resembles a squid. The "squid" are flickered along the surface and the tuna, striking viciously, are swept aboard by a carefully timed heave and swing as the expert fisherman strikes simultaneously with the tuna and lifts him over the rail (Anon., 1938).

The barbless hook usually frees itself as the fisherman heaves the tuna inboard and the "squid" immediately is dropped into the water ready for the next fish. If a barbed hook were used it would be more difficult to disengage, and the catches would therefore be much smaller. If the tuna will not take a lure, a plain galvanized barbless hook is fastened at the end of the wire leader, and live bait is used. The hook is passed through the back muscle of a sardine or anchovetta so that it can still swim about.

If the tuna weigh less than 30 pounds each man fishes individually. If the weight ranges between 30 and 50 pounds, the cotton lines of 2 poles are yoked together, to a metal ring, from which hangs a single wire leader and hook and the fishermen work in teams of two. For tuna weighing more than 50 pounds, 3 lines are joined together. This is known as 2- or 3-pole fishing, and its success requires each team to work together in perfect unison. Four and sometimes 5 poles are used together in catching the very largest fish.

The amount of catch depends on the readiness of the fish to bite and the length of time they will remain near the vessel. Godsil

(1938) stated "In a fast biting school there is a steady rain of fish upon the decks and it is not uncommon to take 30 to 40 tons in an hour or two * * * Such is not the rule, however. On an average trip, a crew will count upon two or three 'good' days of fishing with a daily catch of 20 to 50 tons. The balance of the catch is less sensational and at times dishearteningly slow. It is far more common to get a ton or two from the first attack into a fresh school, with returns dwindling upon each successive try." This publication contains a thorough discussion of tuna fishing craft, gear and methods.

Purse-seine fishing for tuna is conducted on the same principle as for other species. The special features in tuna fishing are that the set must be made and the net pursed more speedily than for other species, or the tuna will escape. The net is of the typical purse-seine design, but is the largest and heaviest that can be operated. Mackerel purse seines have been used in fishing tuna but are apt to be badly torn, as these nets are too light to withstand any effort of a large tuna to escape.

TRANSPORTING AND UNLOADING

As a rule the fishing vessels also deliver their catches, with the exception of a small amount taken off the coast of Costa Rica, which is frozen in Costa Rica and shipped to San Diego or San Pedro by freight ship. It should also be noted that some of the albacore caught in the newly developed fishery off the Oregon and Washington coasts are landed at Astoria or nearby ports, packed in ice and shipped to California canneries by railway express, insulated motor trucks or by tuna vessels acting as transporters. Some frozen Japanese albacore or "Mebachi" and skipjack, are imported from that country in refrigerated ships and canned in California.

The hold of a tuna fishing vessel is divided into bins by removable partitions of 2-inch planks. These are not painted or given any special slime or moisture resistant treatment though the boards are washed and aired thoroughly when the vessel is unloaded.

In filling a bin, a layer of crushed ice about 6 inches in depth is placed on the bottom. The fish are shunted down from the deck on wooden slides and are laid out in rows in a neat, comparatively even layer. Finely crushed ice is shovelled over the tuna until all interstices between and around the fish are filled and the surface completely covered. The layer of ice covering the surface of the fish is usually from 3 to 5 inches in depth. The refrigeration coils which line the hold are intended to reduce the rate of melting, not to take the place of ice in packing.

Brine-chilling systems have been installed on the more recently constructed vessels. The hold is divided into wells by a series of water-tight bulkheads. The wells on the port and starboard sides are separated by a shaft alley which extends from the engine room to the stern of the vessel. The wells are partially filled with sea water into which the fish are placed. The sea water, which is chilled through a shell and tube cooling system is circulated continuously in and around the fish thus providing, through direct contact, a highly efficient means of heat exchange. A temperature of 28° F. is obtained where sea water is used as a cooling medium.

According to a more recently developed system of refrigeration the fish are first chilled in precooled sea water to 28° F. as previously described. The sea water is then pumped overboard and a precooled salt brine with a density of 18 to 23 percent, held at constant temperature, is thus circulated continuously through the well. A rapid and efficient rate of freezing to temperatures of from 9° to 10° F. is then secured. After continuous circulation for at least 48 hours the dense brine may be removed and the well held dry with the coils. The larger craft are all adopting this system. Only the tuna purse seiners, or smaller "bait boats" continue to use ice. Freezing has resulted in improved quality of raw material and reduced loss in transportation to 4 percent or less.

The fish are not gutted or headed but stowed away "in the round." This is done partly because the fishermen are paid by weight. In addition cleaning the catch before stowing has not been found practical, due to leaching of the flesh by ice, excessive bruising and damage to the flesh during stowage and unloading, and delay in getting the tuna into the hold. It has also been found that dressed fish spoil more quickly and that gutting attracts sharks, making it impossible to fish.

The large "bait boats" may bring in catches of as much as 370 tons of tuna but will average about 200 to 250 tons. The smaller or "local" bait boats, with a comparatively restricted cruising range will bring in catches of from 50 to 125 tons, while the vessels using a purse seine for taking bluefin and skipjack, land catches of approximately 10 to 60 tons.

Equipment and procedure in unloading depend on the location of the cannery. In the Los Angeles area, except at Long Beach, public highways intervene between the factory and the wharf. These plants use iron trucks with deep bodies and three small wheels, holding about 750 pounds each (Fig. 34). The trucks are lowered into the vessel's hold, filled and are then hoisted back to the street by block and tackle operated by the vessel's boom and and winch (Fig. 35). A crew of several men pull and push the loaded truck across the roadway into the cannery. A few plants unload small albacore boats onto wooden conveyors which run from water level to the cannery, passing underneath the roadway. The load is weighed on scales inside the butchering room and the weight recorded by hand. The fish are dumped on the cannery floor where they are graded according to size and condition (Roedel, 1938).

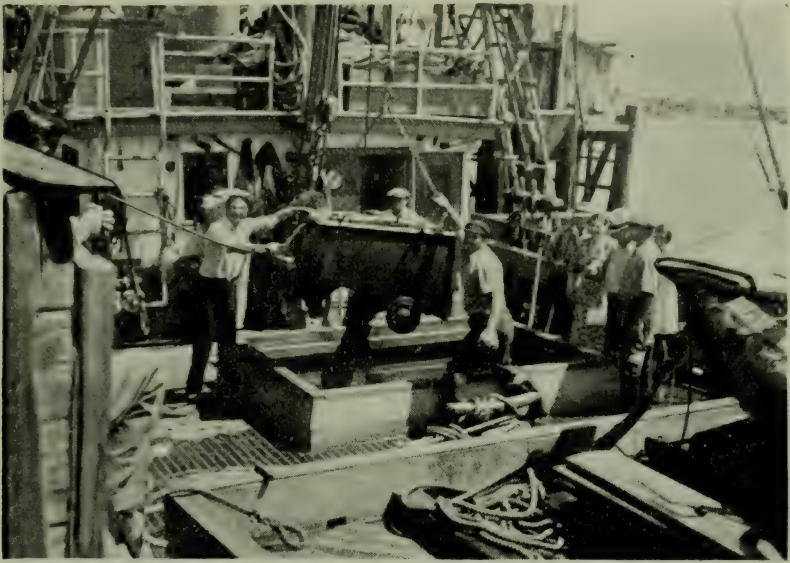

FIGURE 34.—Unloading tuna; preparing to swing a cart of tuna onto the wharf, Terminal Island, California.

In the San Diego area, the canneries extend to the waterfront and maintain their own wharves, with mechanical hoists at the unloading points. The tuna are lifted out of the hold in large iron buckets and are weighed in a weigh house situated by the hoist, or they may be dumped into the apron at the end of a flume, carried a short distance to a weigh house where the weight is taken and recorded by automatic scales, then conveyed by flume to the cannery. In one cannery, trucks running on light rails bring the fish into the cannery while in one or two other instances belt conveyors are used instead of flumes.

THAWING

Tuna stored near the refrigeration coils will be wholly or partially frozen. Imported tuna is always received frozen solid as is fish from the newer clippers. Such fish must be thawed before they can be dressed and precooked. Tuna pre-cooked when frozen will show perforations of the flesh due to the rapid melting of ice crystals formed in the tissues during freezing.

There are two different methods used for thawing tuna. In the Terminal Island (Los Angeles) district, the fish are left to thaw in the open air, where they may be rinsed down from time to time with a water hose. If space is at a premium the fish may be piled in heaps on the floor, rather than in a single layer. At one plant in the Los Angeles area, the frozen tuna are stacked in the racks used in precooking and allowed to thaw.

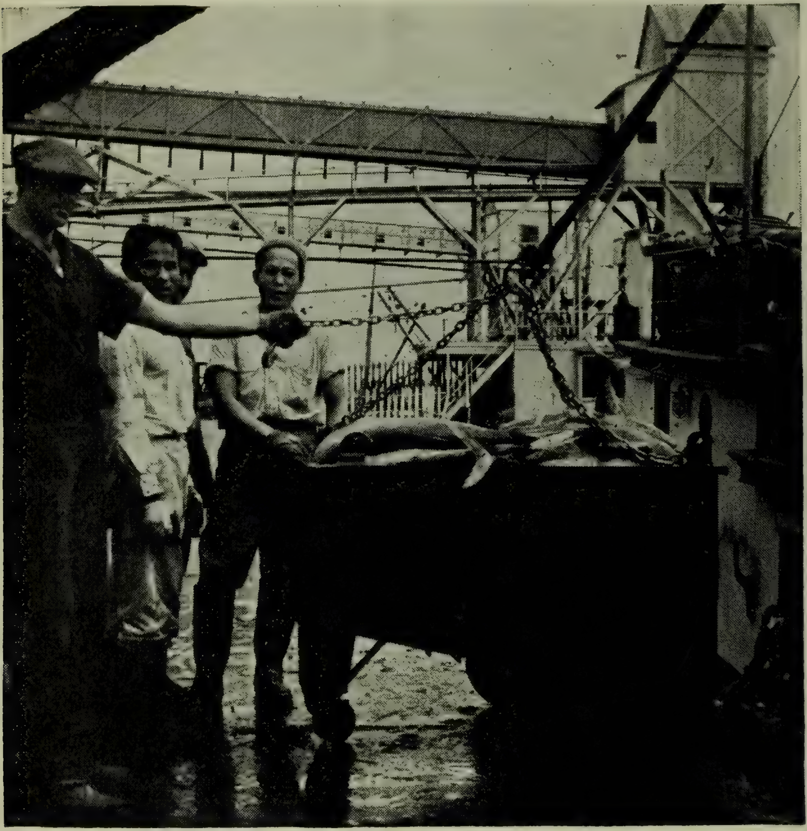

FIGURE 35.—Unloading tuna; unhooking the chains before running cart into the cannery.

In San Diego the usual practice in thawing frozen fish is to hold them in tanks of running water. The tanks may be made of either wood or concrete and are built in varying sizes holding from 1 to 5 tons of tuna. In one large plant an overhead flume conveyor runs between two rows of thawing tanks immediately outside the butchering room. The flume may be blocked so that the fish can be diverted into any particular tank. At the end of the thawing period a sliding door near the bottom of the tank is lifted and the tuna are allowed to flow out into a flume ending in a shallow slanting bin at the head of the butchering table.

The length of time required for thawing varies greatly and depends on whether the tuna are air- or water-thawed, on the size and condition of the fish, on the packer's judgment as to when the fish are sufficiently thawed, and particularly in air-thawing on the temperature and humidity during the process. If thawed in running water, tuna under 10 pounds may be sufficiently soft in 2 to 2½ hours; those weighing from 15 to 30 pounds will require 3 to 5 hours, while larger fish will require from 5 to 8 hours. A great variation in the length of time required occurs in air thawing. During warm weather, with the temperature around 80° F., a small skipjack weighing 5 to 10 pounds may thaw in 4 hours, while in cool weather it may require from 12 to 15 hours. A medium-sized fish may be sufficiently air thawed in anywhere from 12 to 36 hours, and a large tuna may require as much as 48 hours. Frozen Japanese albacore, packed principally at Terminal Island, are left on the cannery floor from 24 to 48 hours before they are considered "defrosted."

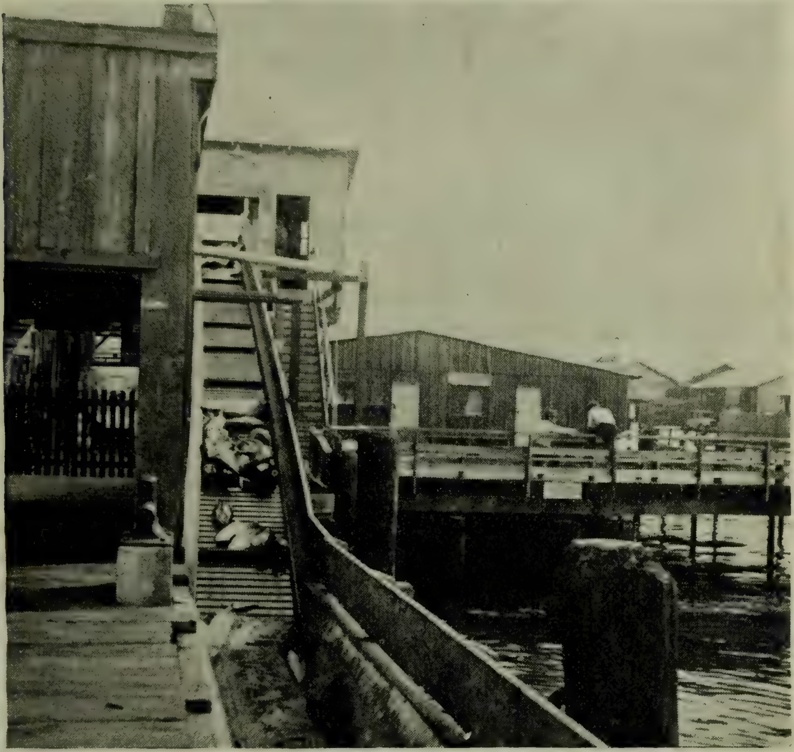

FIGURE 36.—Flume conveyor extending from the wharf into a cannery at San Diego, California. (The tuna are on a slat elevator in transit to the automatic scales.)

The discussion of tuna canning methods refers particularly to California since the industry is at present largely concentrated in that State. (See Fig. 37.) However, tuna are canned in small quantities on the Atlantic coast at Gloucester and in considerable quantities in a new development in the lower Columbia River area. Some of the newest ideas in cannery construction and layout are incorporated in the Columbia River tuna canneries.

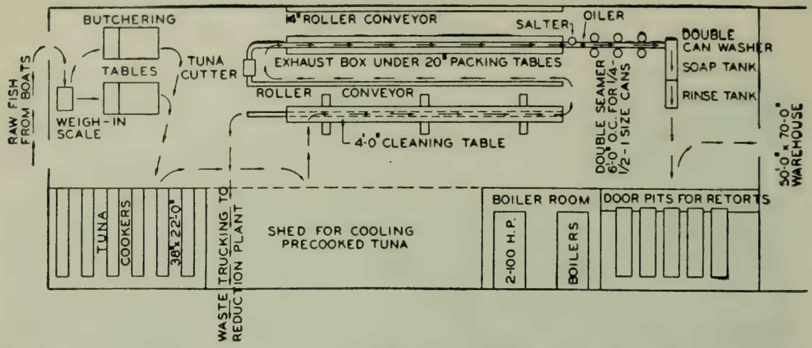

FIGURE 37.—Floor plan of a typical California tuna cannery. (Courtesy, Standard Steel Corporation, Los Angeles, California.)

DRESSING OR BUTCHERING

Two types of tables are used in dressing or butchering tuna. The older type of table, used in plants where fish are dumped on the floor, is portable and built with a small tank in the middle, or at one end. Tuna are washed in this tank after evisceration.

In San Diego plants, the butchering table is a wooden slat conveyor, waist high, running from the end of the flume conveyor inward into the butchering room for a length of approximately 30 feet. The speed of the conveyor is regulated by the rate at which the tuna may be carefully eviscerated and inspected. A man standing by the bin leading from the flume conveyor arranges the fish on the belt conveyor, at a slight angle, bellies toward the operator. The butchers stand next and beside them stands a man who washes out the belly cavities of the eviscerated fish, using a short hose with a spray of water under heavy pressure. At the same time he removes remaining pieces of viscera. He is followed by a State cannery inspector who grades the fish for condition by the odor of the belly cavity. The cannery also has an inspector to cull stale or tainted fish.

One cannery has added a man to the washing and dressing crew. He washes out the gills and mouth of the tuna before they are eviscerated, using a short hose with a long fine nozzle which gives a heavy spray at a force of about 50 pounds per square inch. The tip of the nozzle is inserted under the gill cover, flushing out the gill cavity. This is done so that the odor may be determined more accurately.

In butchering, one worker makes a long slash down the ventral side from the head to the vent, then slashes the viscera free at both ends of the body cavity. Another worker then tears out the viscera. The head and the fins are not removed. The livers are separated from other viscera, since they have been found to contain a high quality medicinal oil, and are packed into 5 gallon cans for sale to drug manufacturers. The remaining offal may be given a short steam cook before it is sent to the reduction plant for manufacture into fish meal.

The dressed and washed fish are placed in wire mesh baskets, which are fitted into wheeled racks of angle iron. Standard dimensions of these baskets are 15 by 30 inches, which will hold 6 small, 3 medium-sized, or one fairly large fish. Sometimes baskets 36 and 42 inches long are used to hold still larger fish. Tuna are stacked in the baskets belly down for better drainage during cooking.

PRECOOKING

The racks of fish are wheeled into horizontal rectangular steam chests where they are precooked in preparation for filling into the cans. The cookers are ranged along one side of the cleaning and packing area, in a separate room, or they may be located in the open air outside. The average tuna cooker is built of sheet iron, is either 13 or 20 feet long, and will hold either 5 or 8 racks, depending on the size.

The chamber must be brought up to cooking temperature gradually if proper cooking is to be obtained. The length of this period varies according to the size and condition of the fish. Tuna brought in fresh usually require less time to reach cooking temperature than fish received frozen, while large sizes must be given more time than small. Length of "come-up" or "lag" time also depends to some extent on the routine practice established by the individual packer. Representative periods are 20 minutes for skipjack and albacore under 15 pounds, 30 minutes for tuna weighing 15 to 30 pounds, 40 minutes for fish 30 to 40 pounds, 60 minutes for tuna 50 pounds weight or larger. The temperature of the precook will average 216° F., though it may be as much as 220° F. The usual custom in cooking is to maintain 1 or 2 pounds of steam pressure in the cooker.

The length of .time required for the precook will vary from 1½ to 8, or even 9 hours. Small skipjack may be cooked in 1½ to 2 hours, but the large bluefin tuna should be cooked 8 hours.[11] General precooking times and temperatures for the various weights and species of tuna are as follows:

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[11] Continental Can Co. "The Canning of Tuna." Bull. Research Dept. Continental Can Co., Inc., 6 pp., New York.

Species	Weight	Time of precook at 216° F.
	pounds	*hours*
Albacore	10 - 14	3 - 3½
Albacore	18 - 40	4 - 4½
Bluefin or yellowfin	8 - 18	2
Bluefin or yellowfin	18 - 50	3
Bluefin or yellowfin	50 - 60	4
Bluefin or yellowfin	60 - 200	5 - 9
Skipjack or striped tuna	5 - 12	2 - 2½
Bonito and yellowtail	5 - 12	2 - 2½

Commercial fishery regulations of the State of California prohibit the canning of tuna weighing more than 150 pounds, but in actual practice the canner usually refuses to accept fish weighing more than 100 pounds, and may even establish 50 pounds as the maximum weight. The reason for this is that the flesh of the larger fish is usually darker in color and stronger in flavor than is desirable for a fancy pack.

When the fish have been sufficiently cooked they are run out into a cooling room where they are held until the flesh is cold and firm enough to handle. If attempts are made to pack precooked tuna before it is sufficiently cool, the flesh will crumble and the separation of skin, dark meat and other waste, is incomplete. The cooling room is often a cross–ventilated area, with screens taking the place of walls but mechanical aids, such as blower fans, are only used occasionally for cooling in hot weather. Length of cooling is regulated by the size of the fish and atmospheric temperature. An average cooling period for most sizes of tuna is 12 hours.[12] Large bluefin tuna are preferably cooled for 24 to 36 hours, as this is believed to give a better texture and color because of longer drainage. The maximum length of time precooked tuna may be allowed to stand without spoilage is 24 hours during warm summer weather. The average loss of weight from precooking runs from 25 to 30 percent. The tuna oil cooked out is sometimes recovered from the steam chests and sold as a by-product.

CLEANING

Cleaning tables may be of several types—including makeshift tables used during rush periods when extra cleaners are required. These are simply flat table tops laid on saw horses and set up in any empty corner. Waste is shoved down holes in the center to fall into containers below. Other permanent tables require waste containers for every two packers. One type is equipped with wide conveyors which run under the cleaning table, carrying all the waste outside the packing room. Comparatively little waste accumulates around this type of cleaning table. Cleaning may be done in a separate room or the tables may be set up close by and parallel to the packing line.

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[12] American Can Co. "The Canning of Tuna." Research Dept., American Can Company, Inc. 6 pp., New York.

Cleaning methods do not vary between canneries or with different species of tuna. The heads are broken off, tails and fins are removed and the skin is scraped away, after which the body is separated into two halves, exposing the backbone, which is removed, together with the adhering rib bones (Fig. 38). The halves are split longitudinally and the dark meat, which is located in a V-shaped layer along the lateral line is scraped away quickly and thoroughly with the blade of a small paring knife. The chunks or strips of light meat are placed on wooden trays 16 by 24 inches in size with two metal strips on the bottom, one near each side. These trays are scalded frequently in a hot alkaline cleansing solution. One packer treats new trays with a liquid synthetic resinous compound to give them an impervious surface.

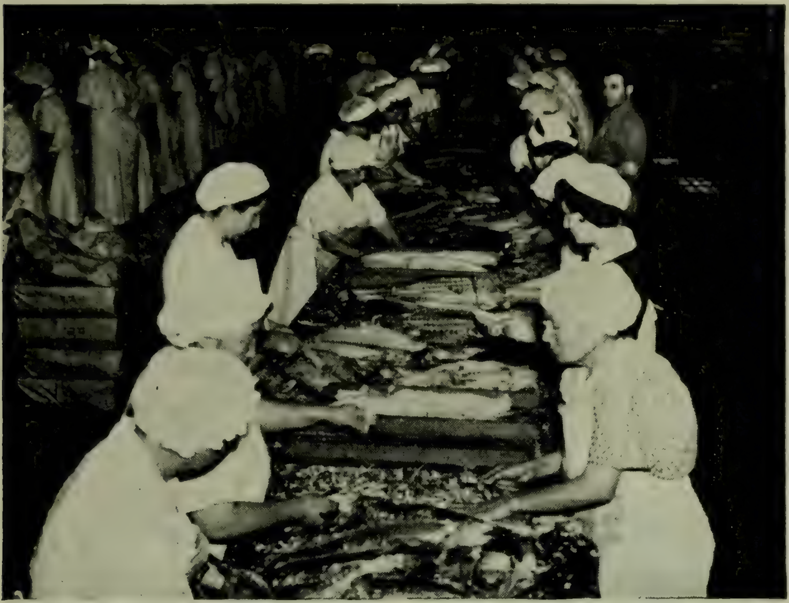

FIGURE 38.—Cleaning cooked tuna. (The light meat used in canning is separated from the bones, skin, dark meat and other refuse.)

The cleaned meat is checked for condition before it is sliced. Inspection includes an examination to determine the adequacy of cleaning, that is, that all dark meat is removed and that no meat unfit for canning because of discoloration, staleness or "honeycombing" is included. The waste may also be inspected before it is discarded to determine that the cleaner is not throwing away light meat. Cleaners are paid on a piece–work basis or they may be assured a minimum hourly wage, with piece–work rates for production over a certain amount. Inspection is very close in some plants, with the checkers making an inspection as they remove the trays, another inspection by the forewoman and a third by a woman stationed by the conveyor taking the sliced meat toward the packing tables.

Cleaning requires more labor than any other operation in tuna canning. If the fish are of average size, cleaning will require two and a half workers for every packer engaged in filling cans; if the tuna are large, the number of cleaners and packers will be more nearly equal, but if the tuna are small the ratio may be four cleaners to each packer.

PACKING

CUTTING

Various types of slicing machines have been used but an automatic cutter of the guillotine type is favored at present (Fig. 39). The trays of cooked meat are carried along a chain conveyor, passing under a blade moving between uprights on each side. A ratchet bar arrangement moves the conveyor forward. Adjustment of the bar, altering the angle at which it engages the ratchet determines the width of the slice. In packing ¼-pound cans of tuna, the slices should be approximately ⅞ inch wide; ½-pound cans, 1 inch to 1⅛ inches, while for 1-pound cans, the width must be 1$\frac{9}{16}$ inches. Some packers cut the large fish only for 1-pound cans. The meat is always cut across the grain.

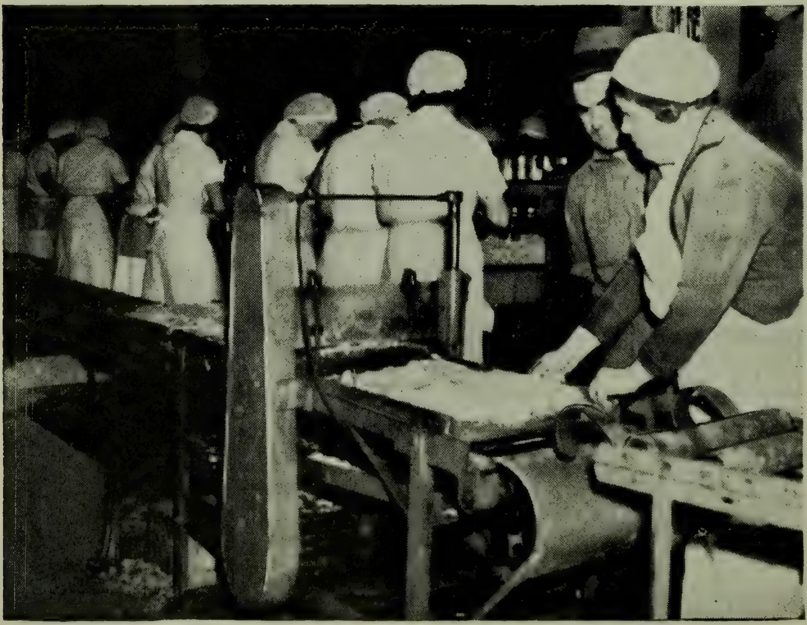

FIGURE 39.—Cutting cooked tuna for the can.

GRADING

Three grades of tuna are packed, namely, "fancy," "standard," and "flakes" or "salad." The "fancy" pack usually consists of large pieces of solid meat with no small fragments. In a "standard" pack, 3 pieces of solid meat are placed in each can, with sufficient small fragments to give the desired net weight. The common practice in packing "standard" tuna is to fill in 25 percent flakes but some packers use no more than 15 percent. "Flake" tuna consists entirely of small crumbs or finely divided meat, packed down into a more or less solid cylinder. (Federal Trade Commission, 1940). If a "standard" pack is being canned, it will use practically all the flake material. "Flake" tuna is usually packed when "fancy" tuna is being canned. Meat going into the flake pack is of the same quality as in "fancy" or "solid-pack" tuna and is by no means a secondary grade product. If the meat is tender and brittle, the amount of flakes will be greater than if the tuna is firm and dry. More flakes are obtained when the tuna are of the smallest sizes.

Species is a factor in establishing the quality of a pack. Albacore has been considered the finest tuna and is the only variety which can be marketed as "white-meat tuna." With the decrease in the catch of albacore, more attention has been paid to developing fancy packs from other species of tuna. Much of the "fancy" pack is now prepared from yellowfin tuna. The catch of this species is larger and more consistent than that of albacore.

FILLING

Details in the setup of the packing table differ among individual canneries. In some plants the exhaust box is built into the center of the packing table, in others it is separate. In some canneries a roller conveyor runs along the top center of the table. Filled trays of meat are placed on this conveyor at one end, to be removed by the packers as needed. In other plants, the cleaned meat is left stacked in the racks which are wheeled around near the tables and a man brings trays from the rack to each packer as she needs fish. This method is slower and it is claimed to cause delays in filling the containers.

The container which is most used in tuna canning is the ½-pound tuna (307 x 113) can. An average of 80 percent of the total tuna pack is packed in this container. (Roedel, 1938.) Other containers used are the ¼ tuna (211 x 109) can, and the 1-pound tuna (401 x 206) can. A small amount is packed in 4-pound cans, mostly flakes for hotel and institutional trade. Most of the packers use plain cans, but as some trouble has been experienced with sulfide discoloration, especially with albacore and catches brought in from the more distant fishing grounds, a number of packers are now using cans with an inside lining of C-enamel, seafood formula.

All tuna are filled into the cans by hand but one packer is preparing to use a filling machine for his flake pack. In filling the can by hand, pieces are selected to fit well into the cans, leaving no spaces around the sides or in the center. As each can is filled with meat, the worker tamps it down quickly with the heel of her hand and places it on the conveyor for filled cans. Balance scales are placed beside each packer but these are rarely used by the more experienced women who have learned to estimate the right amount of fish needed for each can.

Some plants have an inspector on the line to see that cans are properly filled. A ⅜-inch space is left in the top of each can after the meat has been filled in but when the oil is added and the top sealed on, the headspace will not be more than $\frac{3}{16}$ inch after processing. Fill–in weights of meat depend on the moisture content of the fish and are approximately as follows: ¼-pound tuna can, 3½ ounces; ½-pound, 5½ to 5¾ ounces; 1-pound, 11 to 11½ ounces, and 4-pound, 46 ounces.

The filled cans pass along a conveyor to an automatic salt dispenser. The salt used is "three-quarters ground" or "dairy fine." The salt must be handled carefully to prevent clogging, which would cause an uneven distribution of salt in the containers. One packer keeps canning salt in a constantly heated dry kiln, removing a sack only when it is to be used immediately. The approximate amounts of salt used per can are: ¼-pound can, 1/14 ounce; ½-pound, 1/7 to 3/14 ounce; 1-pound, 9/14 ounce, and 4-pound, 6/7 ounce. Salt may be added to the empty can in some instances, but this is not the general practice.

The oil-dispensing apparatus is located on the canning line immediately following the salting machine. The usual type consists essentially of a tank with a single spigot. The flow of oil is constant, falling into a drip pan below when cans are not moving along the conveyor. This excess oil is piped off, filtered and re-used. In some canneries the oil-dispensing machine is equipped with a horizontal length of pipe a few inches above the conveyor. Oil falls into the cans in a series of small jets from holes bored in the bottom of the pipe (Fig. 40).

Winter-pressed cottonseed oil is used, although olive oil is required in at least one specialty pack. The oil is usually added hot at temperatures varying from 180° to 200° F. principally to facilitate handling, but it is claimed that warm oil permeates the flesh more rapidly. The amount of oil filled into each can is supposed to average for 1/4-pound cans, 3/4 ounce; 1/2-pound, 1 1/2 ounces; 1-pound, 2 ounces; and 4-pound, 9 ounces.

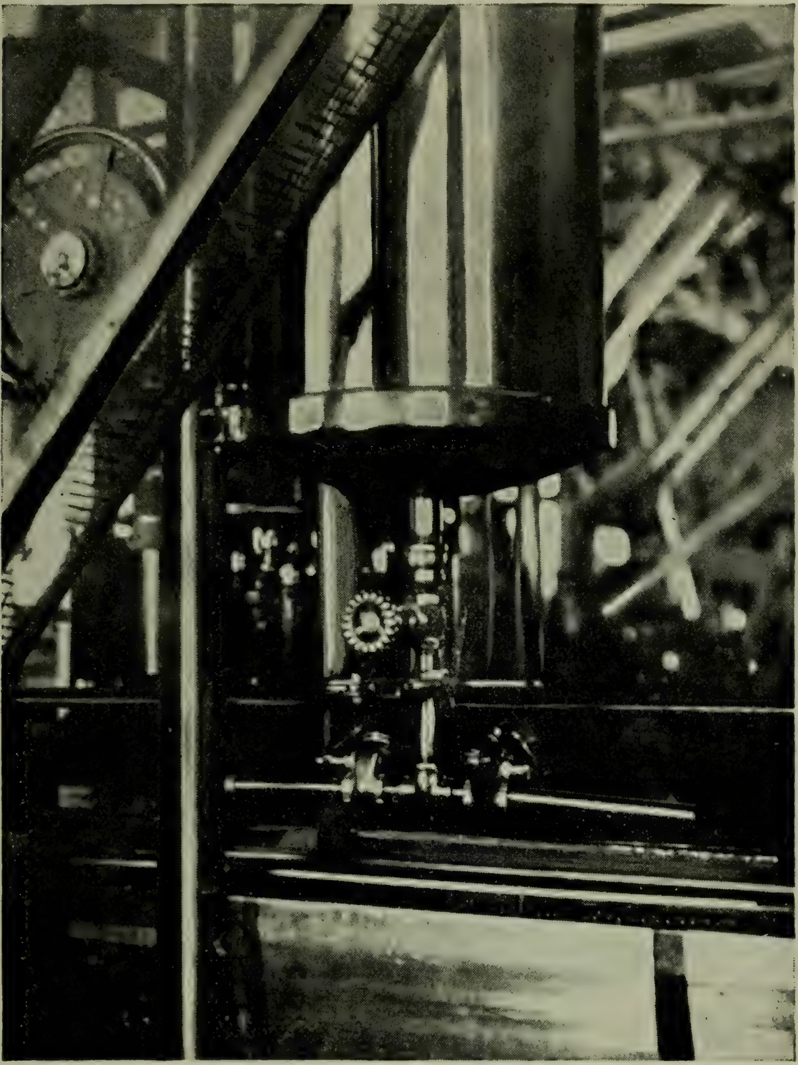

FIGURE 40.—Oil-dispensing apparatus used in tuna canning.

EXHAUST OR VACUUM AND SEALING

The greater part of the tuna pack is still given a heat exhaust in a steam exhaust box, although about one-third of the plants use vacuum closing machines. Covers are not clinched on the cans before exhausting, in most canneries. The exhaust box used has but a single "run," that is cans pass through the box but once. The exhaust is very short, averaging 3 minutes, although an exhaust of 8 to 10 minutes is recommended. The vacuum obtained is very low, not more than 4 and often 2 inches or less. There is a tendency on the part of canners to under exhaust as water condensing in the can will cloud the oil.

Where vacuum closing machines are used, oil is not heated before it is added to the can. After salting and oiling, the cans pass under a machine equipped with a series of plungers. These force the contents into the can so that air spaces are not left on the bottom, which would make it difficult to secure a good vacuum. The cans are then conveyed through a "clinching" machine which drops a lid on each can and crimps it loosely, after which they are carried to the vacuum closing machine, where each can is enclosed in an airtight chamber and the air sucked out by a pump, while the top seam of the can is completely sealed. The vacuum obtained in the cans averages 9 inches. This machine operates at a speed of from 100 to 120 cans per minute. Auxiliary machines may be set up on the line, greatly increasing the speed of operation.

WASHING

The sealed cans roll down a conveyor into the washing machine. Details of these machines differ between canneries but in the usual form the cans pass through a bath of hot alkaline cleansing solution such as tri-sodium phosphate, then through a second bath of hot fresh water and out onto a conveyor, down which they roll into wheeled retort baskets. A baffle of wire mesh or belting at the end of the conveyor breaks the fall of the cans so that they will not be badly dented in dropping into the basket. The baskets are oval in shape to reduce the amount of lost space in the retort and are usually made of sheet metal. State cannery inspection regulations require that the devices, pans, trays, or cages used to hold cans, glass jars, or other containers in retorts should be perforated or made of strap iron so as to insure proper circulation in the retort.

PROCESSING

Horizontal retorts are used in all tuna canneries, but they differ widely in size and capacity (Fig. 41). In California all retorts must be equipped according to the specifications of the State Board of Health. When the retort is loaded and steam is admitted, a period of 7 to 10 minutes is required to bring the temperature and pressure to the required point where the cook actually begins. This is known as the "come-up" or lag time and is not included in the processing time. Official processing times and temperatures are specified by the State Board of Health, and are given in the following schedule:

Can, trade name	Can designation	Initial temperature, degrees F.	Process in minutes at:		
			230° F.	240° F.	250° F.
¼ lb. tuna	211 x 109	70	120	65	40
½ lb. tuna	307 x 113	70	140	75	55
1 lb. tuna	401 x 206	70	170	95	80
4 lb. tuna	603 x 408	70	320	230	190

Although "equivalent" processes at 230° F. are permitted, no commercial pack is processed at this temperature. Most canners process at 240° F. as an additional safety factor. The shorter process at the higher temperature of 250° F. is employed in a few canneries.

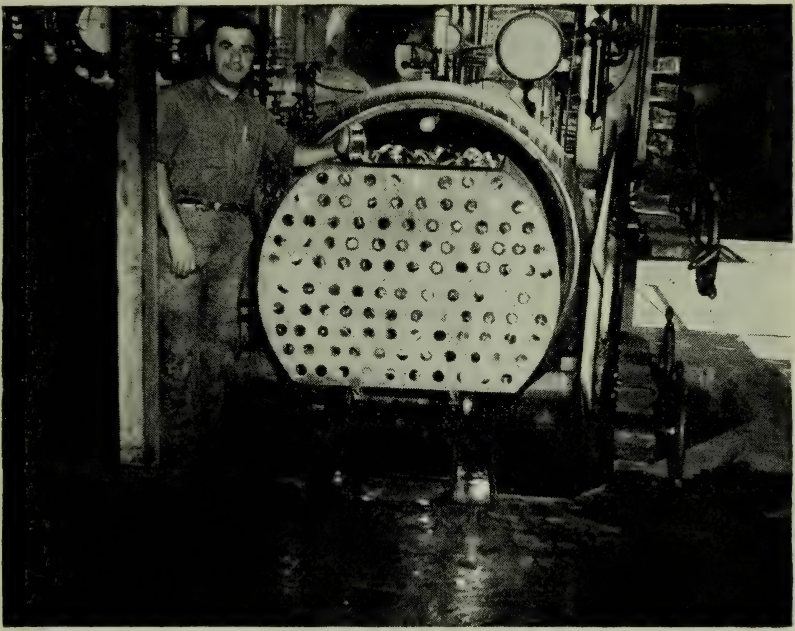

FIGURE 41.—Horizontal retort used in processing tuna, showing the metal basket and arrangement of cans.

COOLING

At the end of the processing time, the steam is shut off and air under pressure is admitted so that the pressure in the retort will be equal to or slightly greater than that during the cook. A spray of water is turned on through a perforated pipe running along the top of the retort. The air pressure is gradually reduced as the temperature decreases. After a period of about 30 minutes the cans have been cooled and the retort may be opened. The cans are still warm to the touch so that the retort crates are wheeled to the warehouse where the pack is held at least 24 hours before labeling.

STORAGE AND LABELING

In California all cans are embossed with a code registered in the State Cannery Inspection Service, stamped into the can lids when they are sealed. All lots are kept separate according to codes, at least until they have been released for labeling and distribution. It is claimed that tuna should be held in storage for at least 3 months as oil and salt will not have penetrated evenly in a shorter time, but in practice some canners do not hold the pack in storage any longer than is necessary to find a buyer. Details of labeling and storage do not differ from methods followed with other fishery products. A standard case of tuna is 48 1-pound cans though it may be packed 48 ½-pound cans to the case; quarters may be packed 48 to the case but in many instances are packed 100 to the case, while 4-pound cans are packed 12 to the case.

SPECIALTY PACKS

TONNO

Tonno is solid tuna meat packed in olive oil and with about double the quantity of salt used for the regular pack. The meat is darker and stronger, as a more pronounced flavor is demanded in this style of pack. Bluefin and skipjack or striped tuna are packed as tonno, with skipjack preferred. Tonno is usually packed in quarter-pound cans although small amounts are canned in larger size containers. A special type of can is often used differing from the ordinary type in that the top end is closed by a crimped sheeting instead of the usual rolled seam. This can be readily removed and the can opened by inserting a sharp instrument under the edge. Tonno is sold principally to the Italian-American trade.

TUNA IN GLASS

Glass containers are sometimes used in packing tuna, particularly tumblers of 3 ½-, 7- and 8-ounce sizes. The method of preparation does not differ from that previously described. Special care is required in filling, as appearance in the containers is a selling feature of this pack. It is prepared only on special order by a few firms.

TUNA IN ALUMINUM CANS

One firm packs a few thousand cases of fancy yellowfin tuna using aluminum cans in ¼- and ½-pound sizes. The method of preparation, the amount of salt and oil, and other packing details do not differ from the usual style of pack. Tuna makes a very good appearance in aluminum cans, with no sulfide discoloration. The container has a re-use value since it is adaptable for use as a salad mould or small refrigerator dish when empty. The cannery preparing this pack has installed brass conveyor belts from the filling table to the seamers, as iron conveyor belts mar and stain the aluminum can. Sealing aluminum cans requires much more careful control than for tin cans because the metal is so soft. The top seam is wider and thicker than in the ordinary can. Because aluminum cans are much higher in cost than tin containers, the pack is limited to the quantity of advance orders.

CREAMED TUNA

Canned creamed tuna is a novelty pack prepared by a single firm. This pack is canned in No. 1 Eastern Oyster, or 12-ounce tall cans. The method of preparation is much like that used in the canning of New England fish chowder. Cooked tuna meat of strictly fancy quality is diced into cubes and filled into the containers, about 4½ ounces to a No. 1 Eastern Oyster can and 5 ounces in the 12-ounce can. The cans are mechanically filled with a hot cream sauce and the covers are sealed on immediately. A standard cream sauce formula, such as is used by the housewife in preparing creamed chicken or tuna is employed, but the consistency of the sauce when added must be thinner than in home cooking since the heavy process thickens the sauce. The process used is 75 minutes at 240° F.

GARLIC FLAVORED TUNA

A pack of fancy yellowfin tuna is now on the market, with just enough garlic added to each can to give the meat a piquant but not obtrusive flavor. There is no change in packing methods, other than the addition of the garlic.

VENTRESCA

Ventresca is a specialty tuna product following the Mediterranean rather than American method of precooking. The belly strips of large fat bluefin weighing 50 pounds or more, are cut into pieces that may be filled into ½-pound cans. The skin is not removed. The chunks of tuna are boiled in a strong salt brine until cooked. After cooling and draining a single piece is packed in a ½-pound tuna can, together with an extra quantity of olive oil. The regular cook for this size can is used in processing.

INSPECTION AND EXAMINATION

In California the inspector assigned to each tuna cannery boards a fishing vessel when it arrives, examines the catch and records the source of the tuna (where caught), the length of the voyage, approximate quantity of different species, the condition of the fish and whether it has been preserved by ice or mechanical refrigeration. The odor is noted and sample fish are thoroughly examined after which permission is given to unload.

The inspector observes the fish through the various stages in packing. In addition to inspection at time of butchering, already described, he inspects the cooked fish when it is being cleaned in preparation for the can. Fish showing discoloration or honeycombing are discarded by the inspector if this has not already been done by the worker. The odor is determined if the condition is at all doubtful. The meat is again inspected for texture, odor and color after it goes through the slicing machine. Meat rejected after cooking is weighed, the amount multiplied by a standard factor of 3 if the meat is cleaned; by a factor of 2 if head, skin and bones are included, and the total is deducted from the amount delivered by the fishing vessel.

The inspector notes all codes used in the daily pack, and close control is maintained over details of processing. At the end of the day, an inspector draws a representative sample of each code packed. If the condition of any lot is doubtful, additional samples are drawn to determine the extent of the defect and the pack is restrained until official instructions based on laboratory examination are issued for final disposal. Samples are cut by a trained examiner who makes out a cutting report covering the sample. The examination is not as detailed as for sardines. Odor only is noted. Most examiners empty the contents of the can and determine the odor at the bottom of the container. A certificate is issued releasing the code or codes for shipment, if production records and processing temperature curves are satisfactory and no stale or off-odors are noted.

MACKEREL

Mackerel are packed at Gloucester, Mass., and Portland, Me., on the Atlantic Coast. The mackerel canning industry of the Pacific Coast is confined to the southern California area, with San Pedro as the most important center. Mackerel are also packed to some extent at San Diego and in small amounts at Monterey.

EASTERN OR "BOSTON" MACKEREL

A pack of eastern or "Boston" mackerel has never been prepared in more than comparatively small quantities due to competition with California canned mackerel. The canning season is approximately from July 15 to November 1. The mackerel used in canning are caught by purse seines. They are iced down in the hold of the fishing vessel as soon as caught and usually have been out of the water from 24 to 36 hours when landed at the cannery.

The mackerel are hoisted out of the hold in large tubs holding about 500 pounds each, and are piled near the cannery door. A workman lays the fish in slots on a conveyor which carries them past automatic knives set to cut the mackerel into can-length pieces (4¼ inches). The cut fish pass to dressing tables where the belly is split open and all offal is removed by hand including the kidney, which is the dark streak along the backbone.

The fish are washed thoroughly in 2 or 3 successive waters, each time for about 15 minutes, and are then put into wicker baskets to drain from ½ to 2 hours. The baskets are carried to filling tables where the mackerel are filled into cans which are usually inside lined with "C" enamel, seafood formula. Heads and tails are alternated in filling and no small pieces are used to fill up the can. Some packers use no spices or condiments but others may add a bay leaf to each can. No. 1 tall cans are filled to a declared net weight of 14 ounces, while the stated net weight of No. 2 short cans is 16 ounces. The cans are exhausted for 10 minutes at 200 to 212° F., sealed by an automatic can seamer and processed for 75 minutes at 240° F. The pack is water-cooled immediately after processing.

Some Atlantic Coast mackerel are canned as "fillets of salt mackerel." In preparing this pack the fish are headed and cleaned by hand, taking care to remove viscera, congealed blood and other offal as completely as possible. The cleaned fish are placed in wooden tanks, half filled with brine testing 90 to 100° salinometer, where they are left for about 12 hours, the exact length of time depending on the size and fatness of the fish and on the judgment of the packer. When brined sufficiently, the fish are filleted and the fillets are filled into oval cans of the type used for California sardines, which are lined with "C" enamel, seafood formula.

Two fillets are placed on the bottom of the can, then a piece of vegetable parchment paper is laid in, and two more fillets are placed on top. The cans pass along a conveyor under a perforated pipe which fills each can with hot brine. This brine is made in the proportions of 20 pounds of salt to 100 gallons of water, to which is added 1 quart of white distilled vinegar of 6-percent acidity. The cans are sealed in a double seamer without heat exhaust, or the use of mechanical apparatus to secure a vacuum and are processed for 75 minutes at 240° F. The pack is water-cooled immediately after processing.

The cans are not labeled, but are packed in individual lithographed pasteboard cartons. Fiberboard cartons holding 1 or 2 dozen cans are used as shipping containers. The cans are filled to a declared net weight of 12 ounces but usually contain somewhat more than this weight. The total loss in weight is estimated at 50 percent.

PACIFIC MACKEREL

The Pacific mackerel *(Pneumatophorus japonicus diego)* belongs to a different genus than the common or "Boston" mackerel of the Atlantic Coast *(Scomber scombrus)* although both belong to the same family (Scombridae). To the layman, the Pacific mackerel differs but slightly from the common mackerel in external appearance, the principal distinguishing characteristics being that the stripes or reticulations are finer and closer together, while dark green rather than blue predominates as the color of the back. Both species are about the same in size, but the fat content of the Pacific mackerel is much lower.

FISHING AREA AND METHODS

Walford (1931) gave the range of the Pacific mackerel as Puget Sound southward to along the coast of Lower California and possibly farther south, the southernmost limit not being definitely recorded. It is not common north of Santa Cruz County, Calif., and the largest catches are made in the Los Angeles area. The Pacific mackerel are taken off the coast of California throughout the year, but the principal season is from July to November.

Pacific mackerel are taken commercially by purse seines, ring nets, set and hand lines, with ring nets as the most important type of gear. Mackerel canning became important about the time that ring nets were being displaced by purse seines in fishing for sardines. Many of the lampara and ring-net boats which had been fishing sardines turned to mackerel fishing. The ring net was found to be better suited to this fishery than either the lampara net or purse seine. Sardine ring nets were used at first but these required too much time to haul, so special nets were made with larger mesh and smaller bags, which could be hauled in less time. The Pacific mackerel do not run in large schools, so many hauls must be made to obtain a load.

The ring net varies in details of construction, and the design has been influenced by the purse seine. Fry (1931) stated:

> * * * the ring net, like the purse seine, has purse rings along its lower edge. Some of the chief structural differences between the ring net and the purse seine are that the purse seine is made of comparatively heavy tarred webbing, is practically uniform throughout its entire length, and is practically square on the ends; while the ring net, like the lampara, is made of light tanned webbing, is gathered on the ends, and is made in three parts; a central "bag" of fine webbing and two end portions or "wings" of coarse mesh. The relative lengths of bag and wings vary greatly. The bag may be from one-fourth to almost the entire length of the net.

In day time, schools of mackerel are located by signs such as flocks of sea birds hovering at the surface, dark patches of water, or numerous flecks of foam made by the mackerel when they break at the surface. If signs of mackerel are not present the captain may trust to luck or knowledge of the fishing grounds. The fishing boat stops at the selected spot where "chum" (ground fish, usually mackerel) is thrown into the water. If sufficient mackerel are attracted to make a set worth while, a skiff is lowered with a man who continues to chum, to hold the school together and keep it quiet. The fishing boat backs away from the spot. When it has reached a distance of about 100 to 150 feet from the skiff the small kegs attached to the end of the net are thrown overboard, the boat is turned and commences to circle the spot including the skiff, requiring about 2 minutes for this operation. The net is payed out as the boat makes the circle.

When the boat has completed the circle, the keg floats are picked up and the set is complete. The bottom of the net is pursed together, the bunched rings are pulled up against the pursing davit and they, with the head line, are hoisted aboard, after which "chumming" is discontinued by the man in the skiff, but not before. The wings are hauled in, with half the crew working on each wing, then the finer meshed bag, until the mackerel are concentrated in the bunt of the net, which is brought around opposite to the hatch. The fish are then loaded into the hold by a brailing net.

Mackerel ring nets are also fished by night, the method differing, since the schools are located by luminescence in the water and chumming is not employed as mackerel seem to run in denser, larger schools. A detailed description of the construction and operation of rings nets, purse seines and other gear used in taking mackerel may be found in "The California Mackerel Fishery" (Croker, 1932).

TRANSPORTING AND UNLOADING

The fishing boats bring their catches into the canneries, since the fishing grounds are only from 30 minutes to 5 hours distant. If a capacity catch has been secured, a deckload is carried. The fish are not iced, as a rule, although this should be done if the catch is made at some distance from the cannery. An awning should be rigged above the deck to protect the fish against the sun, if the vessel is carrying a deck load. Carelessness in handling the catch while on board, as for example walking on the fish, results in bruises which show up in the canned product as dark discolored areas.

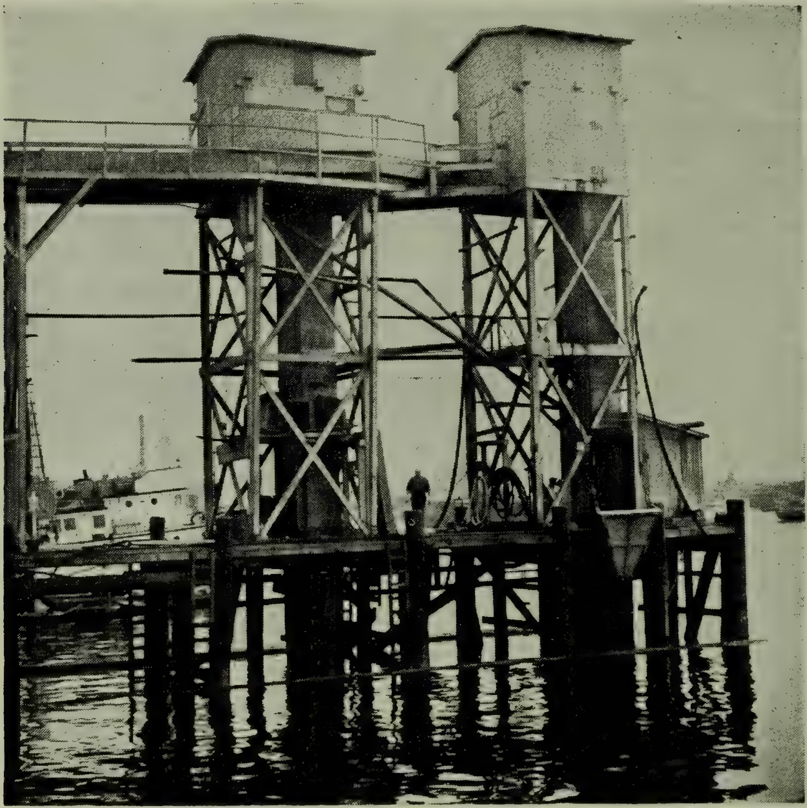

FIGURE 42.—Elevator and conveyor for unloading mackerel and sardine boats at Terminal Island, California.

The mackerel are unloaded onto hoist-or belt-conveyors at San Pedro (Fig. 42) but they are pumped into the cannery at Monterey as described in canning sardines. The fish are weighed in automatic recording scales in lots of 750 pounds. From the scales, the mackerel are flumed into a tank where they are held until used, or they may be emptied directly into bins from which they are delivered to the butchering tables. In California, the inspector stationed at each cannery by the Department of Health, inspects every load of fish to determine their freshness and condition. The fish may not be unloaded until the inspector certifies that they are fit for use. The captain of the fishing boat must report to the inspector the time and date of departure, the time and date of arrival, the location and time of making each set involved in the load and the approximate amount of fish taken at each set. The inspector supervises the unloading, examines the mackerel from time to time as to firmness, and determines the presence of bruised, broken, soft, sunburned, decomposed, or otherwise injured fish.[13] All information is noted in the inspector's mackerel boat report and if data on the report indicate the necessity, the supervising inspector may limit the catch of the boat and require better handling.

The mackerel should be handled as rapidly as possible. Regulations of the Board of Health, State of California, require that fish canned from any individual load shall be prepared and canned within 12 hours of arrival of the boat making the delivery. If the mackerel cannot be canned almost immediately on arrival, they should be covered with finely crushed ice, using at least 50 pounds of ice per 100 pounds of fish, or they should be stored in refrigerated brine at a temperature about 32° F. Mackerel boats fish at night as much as possible, delivering to the cannery in the morning, so the fish need not be held long before canning.

CLEANING OR BUTCHERING

Apparatus for butchering the mackerel and cutting them into container length pieces is being developed to efficient performance and is apparently displacing hand butchering. If the fish are dressed by hand, the head is cut off just back of the gills; the worker then turns the fish quickly, almost simultaneously slashing the ventral surface of the body to the vent, scraping out the viscera. The heads and other offal are tossed into a flume by which they are carried to the reduction plant, while the butchered fish fall into a box with a capacity of about 20 pounds. The workers are paid according to the quantity of fish cleaned.

The mackerel are carried by flume to cleaning tables where other workers scrape out the primordial kidney, the long black "blood streak" along the backbone, trim out any remaining bits of intestines or membranes and complete the washing action of the flume by brushing the fish. Workers then cut the mackerel into container-length pieces, using a mitre box to gauge the proper length of cut. The cut fish are dropped on a belt conveyor by which they are carried to the packing table or they may be emptied into a brine tank.

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[13] Duffy, Milton P., 1935. Instructions to fish inspectors, State of California, Department Public Health, Bureau Cannery Inspection, no pagination.

Machines used are of the same general type as equipment for mechanical dressing of sardines. The fish are placed in deep slots in individual blocks which are the upper part of a chain conveyor and pass under revolving circular knives, so spaced that the head and tail are severed and the body is cut into two container length pieces. Another knife slits the body lengthwise and the fish are cleaned under a rotating brush. A final cleaning is given by hand under running water to remove the last traces of blood. Hand butchering is preferred as doing a better job of cleaning, and resulting in less waste of raw material. With large fish it is possible to obtain three pieces of fish by hand butchering. It is claimed that a crew of 14 can handle from 1 to 1½ tons per hour by hand.[14]

BRINING

The general practice has been to hold the mackerel after dressing and washing for 60 minutes in a brine testing 80 to 90° salinometer. The objective of brining the mackerel is to improve the color of the canned product by soaking diffused blood out of the flesh, making the texture firmer and to give the necessary salt flavor to the finished article. Brining is now eliminated by some packers, who fill the mackerel into the cans immediately after cutting, mechanically adding from 3/16 to ¼ ounce of salt to each can as it comes down the conveyor from the can loft. This is done to save time and reduce the cost of packing, but is undesirable since the texture is usually softer and the flesh darker. Canning technologists recommend that some system of brining be employed.

FILLING

The brined fish are carried by conveyor to a packing table where the containers are filled by hand, women and girls doing the work. Beside or in front of each worker is a case of empty cans. The cans are removed from the case and filled with fish as rapidly as possible. As each case of cans is used, it is replaced by a checker, who punches a piece-work card hanging by each worker.

Mackerel are packed in four sizes of containers. The containers are filled with raw fish to a level slightly above the rim of the can as considerable shrinkage occurs in cooking. Head and tail ends of the pieces of fish are alternated in filling the cans. A 1-pound tall can will usually hold two body sections of mackerel, one whole, the other split, so that a solid cylinder is obtained; or one large piece and two or three small pieces. The fill-in weights of raw fish are as follows:

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[14] Continental Can Co. The canning of mackerel, Bull., Research Department, Continental Can Co., Inc., 8 pp. New York.

Can (trade name)	Can maker's designation	Fill-in weight
		ounces
No. 1 tall	301 x 411	17⅝ to 17¾
No. 1 meat	301 x 407	17 to 17½
No. 1 standard	211 x 400	11½
8-ounce	211 x 304	9⅛

The filled cans are placed on a belt conveyor running along the packing table. An inspector stands at the end of the table, culling out protruding bones, adding sufficient fish to slack-filled cans to bring them to weight and removing the excess from overfilled cans. If the filling shows any amount of careless workmanship, the forewoman checks the individual packers to determine responsibility.

PRECOOKING OR EXHAUSTING AND SEALING

The mackerel are cooked in the open cans until the excess moisture is extracted. As the cans are still warm when sealed, a vacuum is obtained, which is incidental to precooking since the time is much longer than necessary to exhaust the containers. There is no standard length of precook as it varies according to the size of container and the preference of the individual packer. In most canneries the precooking is done in exhaust boxes of the same type as formerly used in salmon canneries, but of larger size.

Other canneries, especially those where mackerel is not a major pack, precook in processing retorts or tuna cookers, the cans being stacked in retort baskets which are trucked to the retort. This practice requires more handling of the product and a greater amount of labor. If exhaust boxes are used, the cans are given a precook of from 20 to 45 minutes at 210° to 212° F. Cans in retorts or cookers are usually heated for a period of approximately 20 minutes at 216° F.

When the cans leave the exhaust box a perforated pipe above the conveyor fills each container with 3-percent salt brine. Some packers do not use brine, especially if the cans have been salted. The addition of brine should not be necessary if the fish have been brined before precooking and the containers are properly filled.

The cans next pass to the closing machines. These are usually set up with an attachment of plungers the diameter of the container. The plungers are adjusted to push the fish down into the cans packing the fish into a solid cylinder and forcing out excess moisture. A runway carries the sealed cans to a washing machine.

The cans roll down a runway from the washing machine into large metal retort baskets, moving on low trucks. An apron of wire mesh is hung below the end of the runway to break the fall of the cans, thus preventing heavy dents but it is not entirely effective.

PROCESSING AND COOLING

The time required to fill one of the large horizontal retorts is about 75 minutes, but there is some variation depending on the size of the retort and the rate of speed at which the closing machines are operating. The temperature in the center of the first cans placed in the retort should be approximately 130° F. when processing begins. Processes worked out for canned mackerel are based on this initial temperature. Excessive delay in filling the retort or in starting processing may, therefore, affect the sufficiency of the process. Control of processing by the Bureau of Cannery Inspection, California State Board of Health, guards against such delays. No. 1 Tall or No. 1 Meat cans must be processed 90 minutes at 240° F. (10-lb pressure) or 75 minutes at 250° F. (15-lb pressure). No. 1 Standard or 8 oz. Eastern oyster cans are processed 75 minutes at 240° F. or 60 minutes at 250° F.

The cans are usually water cooled to a temperature of 100° F. in the retort, by a spray cooling system. The cans are machine labelled and cased after the inspector has marked the batch as released on the production records. The standard case of mackerel contains 48 No. 1-tall cans.

MACKEREL, TUNA STYLE

A small amount of California mackerel is canned tuna style in ½ lb. tuna cans. Only the largest mackerel are suitable for this pack. The fish are headed and gutted, washed, then precooked in tuna cookers using the minimum precook for tuna. Other details in the packing method followed are the same as for tuna. The process given is the same as for tuna in ½ lb. cans. The pack makes a very acceptable substitute for whitemeat tuna, but the cost of packing is higher. The amount of suitable raw material is limited, more labor is required to separate out the white meat and to fill the containers because of the smaller size of the pieces.

MACKEREL FILLETS

Some mackerel are filleted by hand and packed in ½ and 1 lb. oval cans. The fillets may be brined in an 80° to 90° salinometer brine but this is not always done. The fillets are packed in the cans by layers, flesh side up and the filled cans are precooked for 20 to 25 minutes at 210° F. in a long steam exhaust box. Liquid is drained from the cans as they emerge from the exhaust box, using the equipment for draining oval sardine cans. After sealing and washing, 1-pound cans are processed for 65 minutes at 240° F. (10-lb. pressure) or 50 minutes at 250° F. (15-lb. pressure). One-half pound oval cans receive a cook of 55 minutes at 240° F. or 40 minutes at 250° F. The cans are spray cooled in the retort. While most of this pack is canned "natural" style, tomato sauce or spiced vinegar sauce is added to some packs, mostly on special order.

MISCELLANEOUS FISH

A number of other species of fish are canned commercially, but not on a scale requiring an extensive description of methods. A short discussion is sufficient to furnish all essential information. To devote a separate section to each product of this type would involve a certain amount of duplication. Therefore, they are described under a single heading and in alphabetical order.

ALEWIVES

Alewives or river herring (*Pomolobus pseudoharengus*) were first canned commercially as a part of the food conservation program during the first World War, though river herring roe was canned many years previous to 1917. Most of the canning takes place in the Chesapeake Bay area.

Alewives used in canning are caught by trap nets and are usually landed within 3 or 4 hours from the time they are caught. They are hoisted out of the boat, in metal buckets holding approximately 500 fish, into a scaling and washing machine which consists of an inclined, revolving, wire-mesh drum with a perforated pipe running along the axis. As the fish are carried through the drum the scales are removed by the tumbling action. Sprays of water from the perforated pipe wash the fish at the same time.

From the scaler and washer they are carried by belt or chain conveyors to long tables or low platforms fitted with slots, through which waste can be dropped onto belt conveyors, or into buckets or barrels. The fish trimmings are manufactured into meal and oil. Alewives are cleaned by hand, the cleaner first cutting through the black spot just below the gills, then down the side from the throat through the vent, so as to remove the thin belly flesh without cutting into the roe.

After rinsing the fish in fresh water they are placed in a 100° salinometer brine, where they remain from 8 to 12 hours. The exact length of time depends on the size and condition of the fish and is determined by the appearance and texture. The fish must be removed before the skin starts to wrinkle and change color, or before the texture of the flesh becomes too firm.

As soon as the alewives have absorbed enough brine to give the desired texture and flavor, they are cut into container length pieces and piled into small baskets which are taken to the filling table. Holding in baskets also allows surplus brine and moisture to drain away. The pieces are filled into the cans, head and tail ends alternating and empty spaces are filled with the short pieces of flesh removed in cutting the fish to fit containers. The cans are packed with fill in weights of 14, 16, 17 and 19 ounces. A No. 1 tall can with a fill of 16 ounces is the most popular container.

A flow sheet for canning alewives is shown in figure 43.

In some canneries the fish are trimmed to container-length size before brining. Only the extreme tail end is trimmed off and no short pieces are used as fillers. The container used is taller and of greater diameter than the No. 1 tall can, and is known as a 307 cylinder, (307 x 604) or No. 2 tall can. Net contents of this can average 1 pound 9 ounces. Alewives packed in containers of this size are wrapped separately in vegetable parchment paper before filling into the can.

The cans travel from the filling table to the exhaust box, passing under a perforated pipe, from which they are filled with hot brine, usually testing 20° salinometer; or sometimes hot water alone is used. The cans are exhausted by steam at a temperature of about 210° F., and for a period averaging about 3 minutes. This exhaust is insufficient. Cans examined rarely show more than 2 inches of vacuum and often none at all. Exhaust should be increased to 8 minutes or the cans sealed with vacuum closing machines. The exhausted cans are sealed by a standard type closing machine and loaded into metal retort baskets, which when filled are hoisted into vertical retorts.

Processes differ according to the preference of the individual packer. Representative processes are: For No. 1 tall cans, 50 minutes at 244° F. (12-lb. pressure); and for No. 2 tall cans 60 minutes at 250° F. (15-lb pressure). While labeled "fresh river herring," this product most closely resembles and is used in place of, "corned" or lightly salted alewives.

EELS

The market for fresh and canned eels in this country is largely among the foreign population in the cities of New York, Boston and Philadelphia. Some eel products are also sold to the local delicatessen trade among the Scandinavian and German population of the Middle West. These specialties were formerly all imported but the local product has now acquired a portion of the market.

The common eel (*Anguilla rostrata*) is widely distributed. It is found along the Atlantic coast from Canada to Key West and may be distinguished by the slender snake-like form of body; the low vertical fins, devoid of spines, and the absence of ventral fins. The common or "fresh-water" eel varies in length from 2 to 3½ feet and reaches a maximum weight of 16½ pounds.

Eels are caught in eel pots, which are small cylindrical traps usually made of heavy galvanized wire screen with a ¼- or ½-

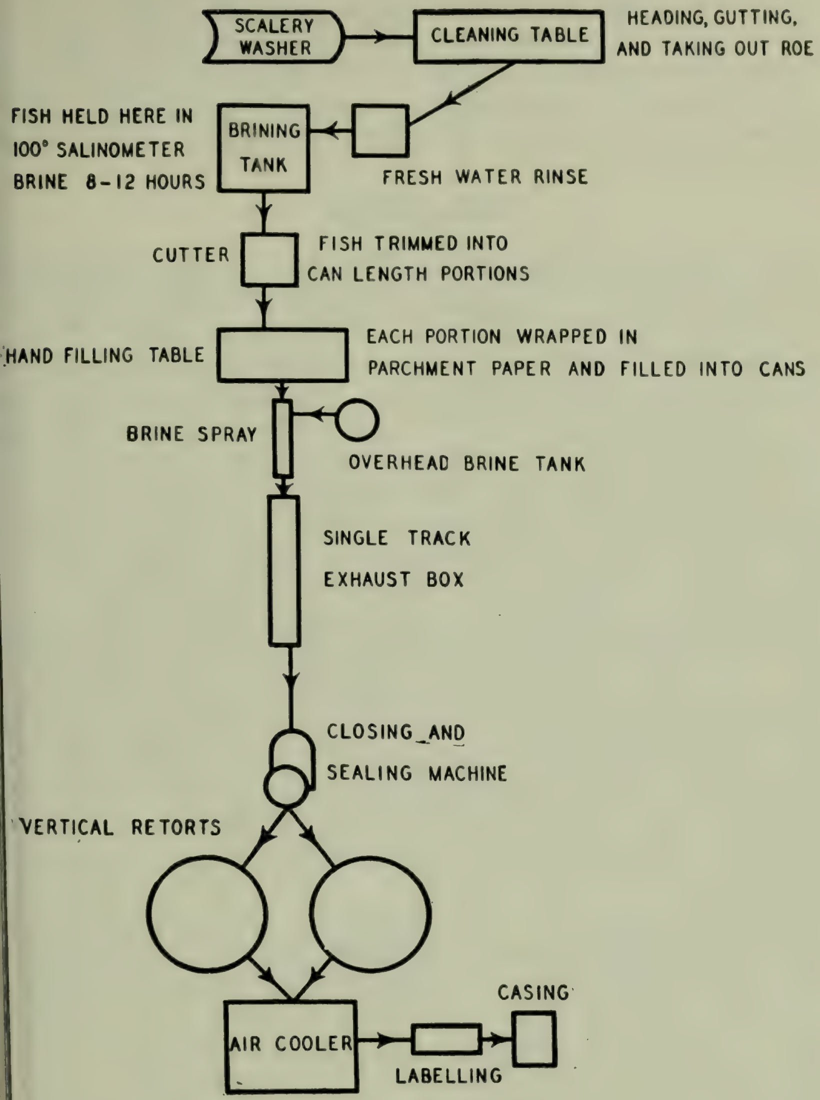
SCALERY WASHER
CLEANING TABLE
HEADING, GUTTING, AND TAKING OUT ROE
FISH HELD HERE IN 100° SALINOMETER BRINE 8-12 HOURS
BRINING TANK
FRESH WATER RINSE
CUTTER
FISH TRIMMED INTO CAN LENGTH PORTIONS
HAND FILLING TABLE
EACH PORTION WRAPPED IN PARCHMENT PAPER AND FILLED INTO CANS
BRINE SPRAY
OVERHEAD BRINE TANK
SINGLE TRACK EXHAUST BOX
CLOSING AND SEALING MACHINE
VERTICAL RETORTS
AIR COOLER
LABELLING
CASING

FIGURE 43.—Flow sheet for canning alewives or river herring.

inch mesh and funnels of cotton webbing in the ends. The eels can enter the traps, which are baited with stale fish waste, but cannot escape through the funnels. The traps are anchored on the bottom of a stream moored to a line, or with a float to mark the location. Eels are also caught by spearing. This is usually done at night. The fisherman carries a torch or lantern, the fish is attracted and dazed by the light, when it is a comparatively easy matter to spear it. Eels are also taken on hand lines, trawl lines, in fyke nets, pound nets, haul seines or "drag nets," otter trawls, and floating traps.

SMOKED EELS

Either fresh or frozen eels may be used. If frozen, they must first be "defrosted" by soaking in a tank of cold water from 4 to 8 hours, depending on size. The eels are dressed, after "sliming" or removing the surface slime by scraping or rubbing with fine salt. They then are split down the belly, from the head past the vent and are eviscerated. The large vein along the backbone should be pulled, or cut out if possible, though this is not always done. After washing thoroughly, the eels are brined from 1 to 2 hours in a 100° salinometer brine. The brining period is shorter than usual in smoking eels but as brining is only for flavoring purposes in canning, a longer time is not necessary.

After brining the eels are dipped in fresh water and scrubbed with a stiff bristle brush to remove any remaining slime or excess salt. If they are not scrubbed they do not color well in smoking. The next step is to string the eels for smoking on pointed iron rods, about ¼-inch diameter, spearing the fish through the head, or passing the rods through the throat cartilage and out through the mouth. The eels are dried in a current of air, until the surface moisture is removed and the surface shows a thin shiny skin or "pellicle."

The eels are smoked for one hour over a low, clear fire without much smoke. Then the fire is damped with moist sawdust and the process continued in a cool dense cloud of smoke until the fish are a yellowish brown in color. The color must not be as deep, nor are the eels hot smoked or partially cooked as in the regular smoking process. Eels are smoked for canning from 3 to 5 hours, depending on smoke density, atmospheric humidity and size of the fish.

After cooling for several hours, the smoked eels are cut in container-length pieces and hand-packed into the containers. There is no standard or usual size of container. The cans used may be ½- or 1-pound flats, ovals, or "square" cans of the type used in packing oil sardines. Some smoked eel is packed in 8-ounce glass tumblers. The cans are filled with olive or cottonseed oil, flavored with bayleaf and allspice, or other preferred spice combinations. The spices are added in the form of essential oils and only a few drops per gallon are necessary. The cans may be exhausted 5 to 10 minutes, or they may be sealed without exhaust or mechanical vacuum. Representative processes used are: For 1-pound cans, 35 minutes at 245° F. (12-lb. pressure) and 80 minutes at 228° F. (5-lb. pressure) ; for ½-pound cans or glass tumblers 30 minutes at 245° F., or 70 minutes at 228° F.

PICKLED EELS

Freshly cleaned and washed eels are cut into pieces about 1 inch thick. These pieces are parboiled for 10 minutes in a solution of 2 percent vinegar with 3 percent salt and 2 ounces of mixed pickling spices to the gallon. The cooked eels are laid aside to drain and cool since they would crumble if handled while warm. The eels are filled into containers, usually glass tumblers holding up to 8 oz. It is understood ½- and 1-pound flat cans are sometimes used. A few fresh dry spices such as mustard seed, celery seed, white peppers and a bit of bay leaf are placed in the container which is then filled with a vinegar-salt solution having an acidity of 2.5 percent and containing 2 percent salt. Eight-ounce tumblers are processed 30 minutes at 240° F. (10-lb. pressure) while 5-ounce tumblers are processed 25 minutes at the same temperature and pressure.

Some pickled eel is packed in a jelly made by dissolving 10 percent by weight of gelatine in water and adding sufficient vinegar to give it an acidity of 1 percent. Dry spices are not added to the containers but a few drops of essential oils of spices are used for flavor. A vacuum-sealing apparatus is used for closing the tumblers or jars. Two of the processes used for both sizes of containers are 20 minutes at 228° F. (5-lb. pressure) and 25 minutes at 221° F. (3-lb. pressure). The pack is water-cooled. To make sure that the eel is "jellied" it is necessary to place the container in a refrigerator for 2 or 3 hours before opening.

FINNAN HADDIE

The haddock should be fresh, free from blood around the backbone and perforations caused by careless use of fish forks. The fish are caught and landed by otter-trawlers. When the haddock are landed they are washed and scrubbed to remove ice, slime or other debris. The fish may then be split along the backbone, to lie flat in a single piece, although they are sometimes left unsplit or "in the round" depending on the size of the fish. Large haddock are usually split, while small ones are not. The heads of unsplit fish are not removed as the smoke stick is passed through the eyes.

Haddock in the round are brined in a salt solution testing 90° salinometer for from 20 to 40 hours, depending on the size of the fish, amount in the tank and amount of smoked fish waiting to be canned. Split haddock are brined 1½ hours in a 100° salinometer brine. As soon as the fish are removed from the tank they are skinned. The skinned haddock are hung on smoke sticks, and "dripped" or allowed to drain and dry for a few hours until a thin skin or "pellicle" forms on the surface.

They are then smoked for about 14 hours over a low smouldering fire, preferably of oak sawdust. The exact length of smoke cure depends on the preferences of the individual packer, the size of the fish, and also to some extent on the weather. Fillets are sometimes used and are given a much shorter smoke cure. The smoked haddock should have a clear light color, with no appearance of reddening in the flesh and should be free from excessive bone or skin.

When the haddock are taken out of the smokehouse, the heads are broken off and the fish are laid in the shallow aluminum pans used for steaming fish in the preparation of fish flakes. These pans are placed in square retorts and the fish are steamed for 15 minutes at 240° F. (10-lb. pressure).

The steamed finnan haddie is broken into pieces, removing the bones and any bits of skin. The cooked fish is transferred to smaller pans which are carried to workers at a filling table. The packers scoop up the hot flakes and fill them into cans holding either 4, 12, or 16 ounces. The filled cans pass to a double seamer and are sealed immediately after filling, without heat exhaust or the use of a vacuum sealing apparatus, as the contents should be sufficiently hot at closing to make other methods of securing a vacuum in the container unnecessary.

The process used for 4-ounce cans is 40 to 55 minutes at 240° F. (10-lb. pressure) and for 12- and 16- ounce cans, 75 minutes at the same temperature and pressure. The pack is water-cooled immediately after processing. The cans when labeled are packed in fiberboard cartons, holding either 12 or 24 cans.

FISH FLAKES

Fish flakes may be prepared from haddock or cod, or a mixture of the flesh of both species, but haddock is probably most often used. This pack is usually prepared in the period after Lent, when large catches are being landed and the market for fresh fish is not so active as at other seasons, making a supply of raw material available for canning. The fish are caught and brought in by trawlers and are of the same quality as those used in the preparation of fresh fillets.

The first step in canning is to wash the whole fish thoroughly, removing all traces of blood, viscera and other offal. When washed and cleaned, the fish are placed in a tank and brined for an average of 10 to 14 hours in a brine 100° salinometer. The length of brining period may vary according to the size of the fish, the total amount to be brined in an individual tank and the strength of the brine. It may be as much as 36 hours.

After brining, the fish are placed in large shallow aluminum pans, which are stacked in horizontal retorts and steamed for about 1 hour at 250° F. (15-lb. pressure). The object is to improve the texture by reducing the moisture content, and to separate the flakes readily from the skin and bones.

Some packers use fillets of haddock, canning that portion of their fillet production which the fresh fish market will not absorb except at prices showing a loss to the packer. Fillets are

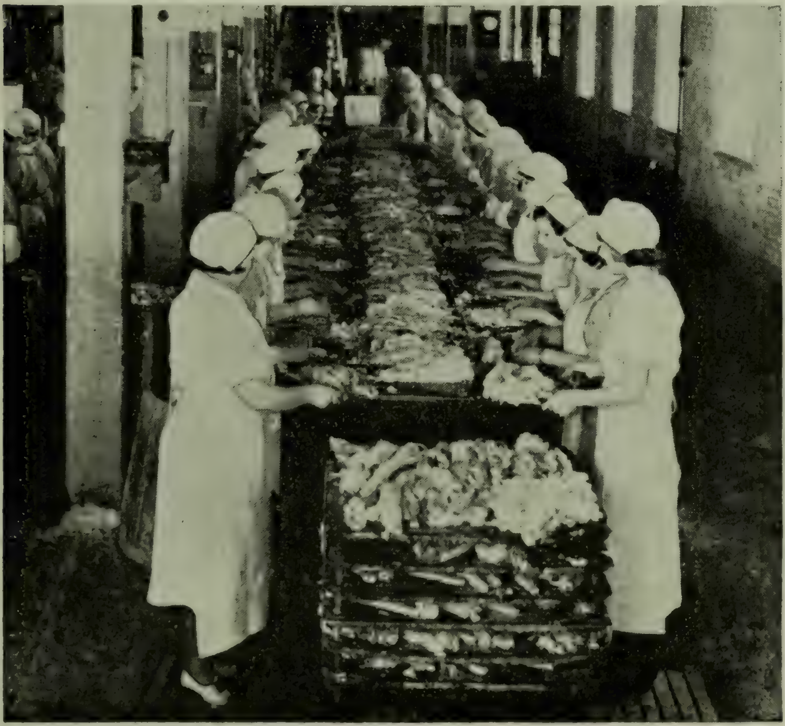

FIGURE 44.—Canning fish flakes; removing the skin and bones after precooking. (Courtesy, Burnham & Morrill, Portland, Maine.)

brined from 1 to 3 hours in a 70° salinometer brine, and steamed for 30 minutes at 250° F. (15-lb. pressure).

The steamed fish are picked free of skin and bones (Fig. 44) and are placed on a circular revolving filling table (Fig. 45). As the cans pass under circular openings around the circumference, packers direct a sufficient amount of fish from the heap in the center of the table into the cans to obtain the required fill.

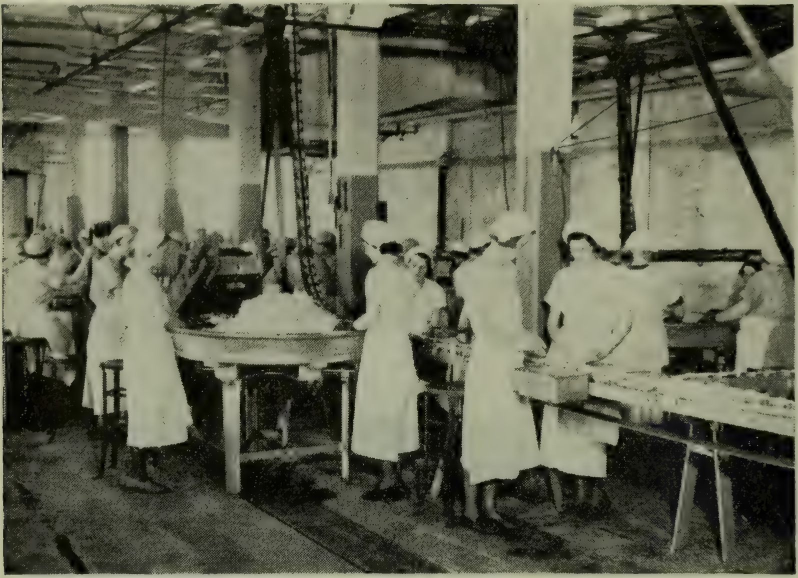

FIGURE 45.—Filling cans with fish flakes. (Courtesy, Burnham & Morrill, Portland, Maine.)

In other instances, especially where fillets are used, the flakes are packed at hand filling tables of the usual type. The hot flakes are turned out of the steaming pan into smaller trays placed by each packer. As the empty cans pass down the conveyor belt on the filling table, they are filled with hot fish scooped up in large spoons from the trays. The filler table conveyor takes the filled cans directly to the double seamer. Since the temperature of the contents averages about 165° F. at sealing, other means of obtaining a vacuum are not necessary. Three sizes of can are used, No. 300, ½- and 1-pound flat and both are lined inside with "C" enamel, seafood formula.

The ½-pound cans are processed for 60 minutes at 240° F. (10-lb. pressure) to 245° F. (12-lb. pressure), while No. 300 and 1-pound cans are cooked 90 minutes at the same temperatures and pressures. The pack is water-cooled and when dry is labeled and packed in fiberboard shipping containers, usually 2 dozen cans to the case.

HERRING

KIPPERED HERRING

Most of the canned kippered herring sold in the United States is imported either from Great Britain or Norway. The former country puts up kippered herring in 1-pound oval cans, while the latter exports kippered herring fillets in various sized containers with the foreign-trade designation of 1/16 (96 x 43 x 17 mm.) (1½ oz.) to the 1/1 square (159 x 105 x 39 mm.) (1 lb.). Of these, the "30 m/m club" (105 x 60 x 29.7 mm.) with net contents of 4½ ounces, is believed to be sold most widely in the United States market. A small amount of canned kippered herring is packed occasionally in Maine and New Brunswick. Kippered herring was canned for a few years in Alaska but none has been packed there for several years. Suitable raw material was plentiful, the product was appetizing, but packing methods were not sufficiently well developed so that it could withstand competition from other sources.

Only the freshest herring, fat and of good quality, should be used for kippering. The herring are split down the back and eviscerated. After washing to remove blood and slime, and after draining they are placed in a 90° salinometer brine for 30 minutes. The brined herring are then hung on smoke sticks. Nails driven at a slight upward angle are spaced at intervals along the sticks, so that when a fish is spiked on 2 of these nail points it is held open. The sticks, when loaded, hold from 12 to 20 fish and are placed in a current of air for 1 to 2 hours or until a thin shiny "skin" or pellicle forms on the surface and free moisture is not apparent. The sticks are then hung in the smokehouse, from 6 to 8 feet above the floor and the fish are smoked over a low smouldering fire of hardwood sawdust.

When not intended for canning, kippered herring are smoked 6 to 8 hours, and this cure is sometimes given to herring prepared for canning. Such fish are darker in color than is desirable, the flavor is likely to be strong or caramelized, and is apt to have an after taste. Kippered herring for canning should be smoked only sufficiently to develop the smoke flavor, and the color should be lighter than for distribution fresh. The smoking time should be reduced at least one-third; that is, to 4 hours.

When the kippered herring are cool enough to handle, they are removed from the smoke sticks, heads and ails trimmed away and the kippers filled by hand in 1-pound oval cans, flesh side up, alternating head and tail ends to secure an even fill. The cans are given heat exhausts ranging from 3 to 15 minutes. The shorter exhaust is not effective and should not be used. Packers giving the short exhaust seal the cans immediately. Some of those giving the long exhaust drain the cans for 30 seconds before sealing. The pack is processed for 65 minutes at 240° F. (10-lb. pressure).

HERRING IN TOMATO SAUCE

The "raw pack" method used in canning California sardines is followed in packing fresh herring in tomato sauce. All details of the method, including draining of the precooked fish, amount of sauce, and processing are the same.

ANIMAL FOOD

Fish for use in animal feeding (frequently called pet food), are canned commercially in the New England States and California, with production about equally divided between the two areas. On both the Atlantic and the Pacific Coasts, animal food is canned as a by-product to utilize material which otherwise would be wasted. In the New England area raw material for pet food canning consists of waste from filleting. In California, whole sardines (pilchards) or mackerel, fresh and of good quality, but unsuitable for canning because of size, are canned for animal feeding.

ATLANTIC COAST METHOD

Filleting waste, mostly heads and backbones, is brought into the cannery by small hand trucks as required. It is pitchforked into large shallow metal pans, about 4 feet square by 6 inches deep, with perforated bottoms. The loaded pans are stacked 4 or 5 deep on a small wheeled truck. The truck is then shoved into a horizontal "Portland" retort, where the raw material is steamed for an average of 60 minutes at 250° F. (15-lb. pressure) though if the scrap is from large fish the time may be 90 minutes, while waste from filleting small fish or "scrod," is precooked for 45 minutes at the same temperature and pressure.

When the material is cooked sufficiently, the retort is opened and the pans are emptied into large sheet-metal baskets of the type used in precooking ingredients for fish cakes. These baskets have a capacity of about 200 pounds each. Loaded baskets are lifted by an automatic hoist and carried by overhead conveyor to a grinder with a 3/8-inch plate. The cooked fish are unloaded into the hopper of the grinder by opening a trap door in the bottom of the basket.

The ground material is discharged onto large shallow metal pans, which are conveyed to a hand filling table, where the fish are immediately filled into No. 1 tall cans to a net weight of 16 ounces, though the declared weight on the label is usually 15 ounces, to guard against occasional variations in weight. The cans are carried by a belt conveyor to a double seamer where the lids are sealed on. Neither exhaust or mechanical vacuum seal is considered necessary as the temperature of can contents at time of sealing averages 160° F.

The process for pet food in No. 1 tall cans is 90 minutes at 236° F. (8-lb. pressure). Some animal food is packed in No. 10 cans for use on fur farms. The process for this size of container is 150 minutes at the same temperature and pressure.

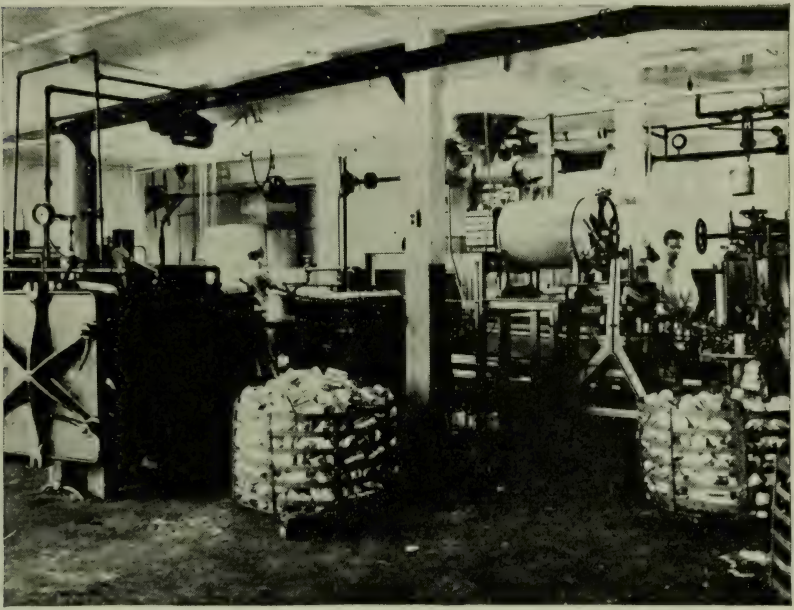

FIGURE 46.—Canning pet food from fish waste. Left, Portland type horizontal retort. Right center, grinder. Right, can closing machine. (Courtesy, Forty-Fathom Fisheries, Boston, Mass.)

PACIFIC COAST METHOD

In addition to Pacific mackerel and sardines, whale and seal meat are utilized in the canning of "pet food" in California. Animal food which includes whale or seal meat is usually of the "balanced ration" type. While these or other fishery products are usually the principal ingredients, they are sometimes supplementary to slaughter-house products. Each cannery uses a secret formula, usually based on the receipt of a veterinarian or successful kennel operator. The following formula is representative:

Ingredients	Percentage by weight
Steamed ground fish or whale meat	35
Steamed cracked cereal	35
Cooked vegetable	10
Water	10
Agar-agar or kelp meal	2½
Dried milk	2½
Dried brewer's yeast	2½
Cod-liver oil	2½
Salt per No. 1 tall can	About ¼ oz.

The cereal used may be cracked wheat, broken rice or barley. The vegetable is usually carrots, although spinach, string beans and tomatoes also are used.

Steamed whale meat or fish is ground, then the other ingredients are added and blended in a beating or mixing machine. The mixture is pre-cooked for about 20 minutes in a steam jacketed kettle until thoroughly heated. No. 1 tall cans are filled with heated material either mechanically or by hand. The fill is 16 ounces while the declared net weight is 15 or 15½ ounces. For No. 10 cans the fill is 7 pounds. The cans are sealed immediately after filling and the No. 1 tall can is processed for 90 minutes at 240° F. (10-lb. pressure), while No. 10 cans are cooked 4 hours at the same pressure and temperature.

The larger size container is bought by kennel operators, fish hatcheries and "fur farms."

In most plants, Pacific mackerel are canned for animal feeding by the batch process. Details differ in various plants, but the following is descriptive of the general method: Whole mackerel are ground, then emptied into an 80 gallon steam-jacketed kettle. About 20 percent of steamed cracked grain or flour is added to the fish. The mixture is stirred mechanically until it is cooked and blended, or from 20 to 30 minutes, then emptied into the hopper of a filling machine. The cans are sealed immediately and given the same process as the pet food previously mentioned. One cannery, the first in California to can animal food commercially, has developed a continuous method of packing.

When sardines (pilchards) are used in preparing a canned animal food, the fish are fed into a steam cooker of the type used in the manufacture of fish meal. The cooked fish pass into a screw type press, where they are pressed until the oil content has been reduced to about 2 percent, but not to such an extent that the moisture content is reduced below 65 percent. The pressed mass is filled into No. 1 tall or No. 10 containers, to which is added the press liquor minus oil which has previously been condensed to approximately one half the original volume in a triple effect vacuum pan. The cans are sealed immediately without heat exhaust as the temperature of the contents averages from 150° to 160° F. when filled. In some instances cereal is not added, the product consisting solely of ground cooked fish.

Animal food made from fish is such a recent development of the canning industry that it is still in the experimental stage. Reliable packing data are lacking, and a research study must be made before a more detailed description of methods and processes can be published.

SHAD

The canning of shad is confined to the San Joaquin and Sacramento River districts in California and to the Columbia River area. Few shad are canned on the Atlantic Coast as the entire supply is usually taken by the fresh fish market, and even when there is a large supply at lower prices than usual, canners cannot afford to compete with fresh fish dealers. Shad are canned as a by-product to the canning of shad roe and at times when market conditions make it unprofitable to ship Pacific Coast shad to the fresh fish markets of the Atlantic Coast.

The shad catch of the Pacific Coast is incidental to the salmon catch. Most of the shad are taken in salmon gear by men who are fishing for salmon. In California and the coastal district of Oregon, salmon drift gill nets varying from 150 to 350 fathoms in length and with a mesh size of 5½ to 6½ inches, stretch measure, account for the entire catch. In the Columbia River district the catch is taken about equally by salmon gill nets and the haul seines operated on sand bars near the mouth of the Columbia River. The greatest part of the catch is made in June.

Shad are canned salmon style. The shad are scaled and scraped, after which the head, tail and fins are removed. A cut is made down the middle of the abdomen, and the shad are eviscerated, the body cavity scraped to remove all traces of blood and membranes, and washed thoroughly.

When cleaned and washed the shad are cut into can-length pieces by machine. The operation of these machines is described under the discussion of salmon canning. The cut pieces are automatically filled into cans, usually No. 1 tall salmon, after which the containers are weighed and the lids are sealed on by a vacuum seamer. A heat exhaust of 10 minutes at 212° F. is used if the fish is packed in ½-pound flat cans and the containers are sealed by an ordinary type closing machine. The process for 1-pound tall cans is 90 minutes at 240° F. (10-lb. pressure) and for ½-pound cans 80 minutes at the same temperature and pressure.

The texture of canned shad is slightly soft, but sufficiently firm so that the contents of the can should be removed in a solid cylinder. The color of the flesh is somewhat darker than that of freshly cooked shad.

KIPPERED SHAD

A small amount of shad is lightly smoked or "kippered" and packed in ½-pound flat salmon cans. This is distinctly a specialty product and is only canned on occasion and in lots of a few cases, although it makes an excellent hors d'oeuvre or sandwich filler.

The shad is scaled under a pressure jet of water and the head, tail and fins are removed. A split is made down the back, inserting the knife on the upper side of the backbone, with the edge of the blade at a slight downward angle so that an even cut will be made with little flesh adhering to the backbone. If the cut is made properly it should be possible to open the shad in a single flat piece from the napes to the tail. After splitting, the shad are eviscerated and scraped free of all traces of viscera, blood and other offal. The dressed fish are washed thoroughly and allowed to drain.

When sufficiently drained the shad are brined from 1 to 2 hours in a 90° salinometer brine. Since brining is for the purpose of flavoring only, an hour should be sufficient. The brined fish are fixed on smoke sticks, then hung in a strong current of air, until no traces of surface moisture are to be observed and a thin, shiny "skin" or pellicle has formed on the surface.

The shad are then ready to be hung in the smoke house, where they are given a smoke cure at a temperature of from 70° to 90° F. They are smoked over a low fire giving off a light smoke for the first 2 or 3 hours. The fire should then be covered with sawdust, producing a dense smoke until the surface of the flesh is straw yellow in color. The entire smoking process will require 5 to 12 hours, varying according to the size of the fish, weather conditions and the type and size of smokehouse. The smoke cure should not be heavy. Oversmoking makes the flavor of the canned product disagreeable.

The smoked fish should be cooled in a current of air. When cooled the shad are cut into container-length pieces and filled into ½-pound cans by hand. Some packers add about 1 oz. of a weak salt solution, made up in the proportion of 1 ounce of salt to a gallon of water, although 1 ounce of salad oil may be used instead. The covers are then clinched on loosely and the cans are given a heat exhaust of about 10 minutes at 212° F. After exhausting, sealing is completed and the pack processed 70 to 80 minutes at 240° F. (10-lb. pressure).

STURGEON

Three species of sturgeon are canned in the United States. The common sturgeon (*Acipenser sturio*) is found along the Atlantic Coast from Maine to South Carolina, but is now taken principally in New Jersey and Virginia. Large-mesh gill nets were formerly used in fishing but most of the catch is now made in pound nets incidental to other fisheries. This species has been greatly depleted in numbers through overfishing and water pollution.

The green sturgeon (*Acipenser medirostris*), has a distribution from northern California to Alaska, but the commercial catch is now almost entirely taken in the Columbia River area. Small sturgeon are taken in salmon gill nets, but the large ones are only caught by the use of set lines, specially made of strong rope with a large iron hook. The green sturgeon may reach a very large size. Cobb (1919) stated that the record weight is 1,000 pounds, with a length of 13 feet.

The third species canned in the United States is known as the Caspian sturgeon (*Huso huso*) imported as frozen fish from the U.S.S.R. Caspian sturgeon may include other species such as *Acipenser mediventris* and *Acipenser ruthenus* as the common name apparently is used rather loosely for several species.

PLAIN OR IN TOMATO SAUCE

The sturgeon is cut into pieces which can be fitted into the container. These are washed, brined in a 90° salinometer brine for about 1 hour, and packed into the containers by hand. The cans are precooked in an exhaust box or hot water bath at 212° F. for a period varying from 30 to 60 minutes. The cans are then inverted for 1 or 2 minutes to drain the excess moisture. In some instances the cans are sealed without using any sauce. In others about 1 ounce of heavily spiced tomato sauce is added to ½-pound, and 1½ ounces to 1-pound containers. The process for ½-pound flat cans is 75 minutes; and for 1-pound flat cans, 90 minutes at 240° F. (10-lb. pressure).

KIPPERED" OR SMOKED STURGEON

"Kippered" sturgeon (smoked sturgeon) is canned commercially in the Columbia River area. Both fresh and frozen sturgeon are used. Frozen sturgeon must be first thawed in tanks of cold water, overnight or for a period of 8 to 10 hours. The fish are cut into chunks weighing about 1 pound each, which are held in a 90° to 95° salinometer brine for 2½ to 3 hours, the exact time depending on the size and thickness of the pieces. The brined chunks are then rinsed in fresh water, after which they are allowed to drain for a few minutes and are placed on ¼-inch mesh, wire-bottomed wooden trays. The wire should be rubbed with lard oil before use to prevent sticking of the flesh. The pieces of fish are placed in the trays so that no two chunks touch.

The trays are placed in racks in the smoke house, from 8 to 12 feet above the fire. The chunks are allowed to drip and dry for a few hours, after which a low fire is started and the fish are smoked at a temperature not higher than 80° F. from 4 to 8 hours, depending on the density of smoke, the size of the pieces and the atmospheric humidity. The fire is then built up so that the temperature is 175° to 180° F. and the fish are smoked at this temperature for one-half hour.

The trays are taken out of the smokehouse and the fish are allowed to cool. When the smoked sturgeon is cold and firm enough to handle, it is taken to tables and packed by hand into ½-pound flat salmon cans. Three tablespoons of olive or cottonseed oil is added, after which the cans are exhausted for 10 minutes at 210° to 212° F., sealed and processed for 70 to 75 minutes at 240° F. (10-lb. pressure). The cans are air cooled.

SHELLFISH

CLAMS

BUTTER CLAMS OR LITTLE NECK CLAMS

Butter clams (*Saxidomus nuttali*) and little-neck clams (*Tapes staminea*) are found in Oregon, Washington, British Columbia and Alaska, where they are canned in varying quantities, principally in the Puget Sound area.

The clams are found in gravel beaches, between tide lines and are obtained by digging. Both species of clams inhabit the same beds and are usually canned without attempting separation by species. The clams are washed off roughly as they are dug, then packed in burlap bags holding about 100 pounds each. These bags may be brought in from the Puget Sound beaches by boat, but an increasing amount is transported to the cannery by motor truck.

So far as can be determined, the practice of holding the clams for 24 hours in tanks of water in which corn meal has been thrown so that their stomachs will be emptied of waste, reported by Cobb (1919), is no longer followed.

The clams are washed thoroughly on arrival at the cannery and any broken-shelled or dead clams are discarded. They are loaded into "coolers," strap-iron trays used for holding salmon

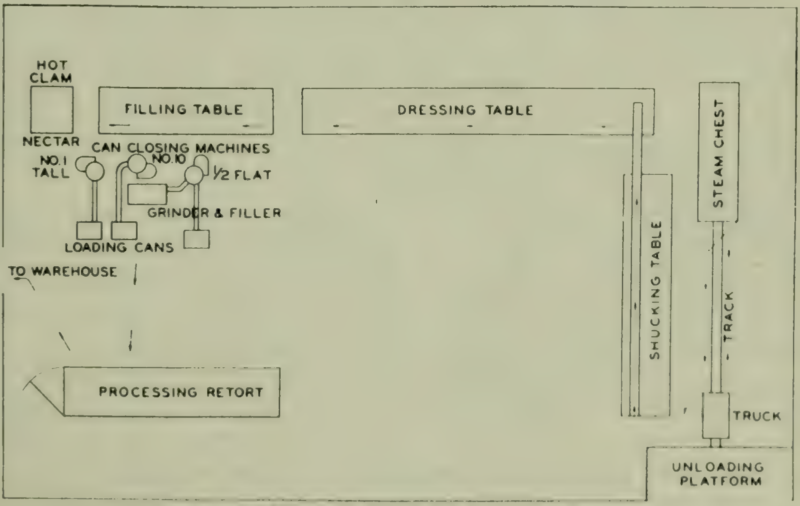

FIGURE 47.—Floor plan showing the equipment layout of a Pacific Coast cannery for butter clams. (From *Pacific Fisherman*.)

cans in processing, which are placed four tiers high on low trucks. The trucks are run into a 4-truck horizontal retort, equipped with drip pans for catching the juice. The clams are steamed in the shell for 15 to 20 minutes at 212° (0 pressure) to 228° F. (5-lb. pressure).

The "coolers" of steamed clams are trucked to the shucking table. In one cannery this is a high table covered with galvanized sheet metal and placed parallel to the track to the steam chest. The table is built with a high back and a metal flume runs to the dressing table. The clam meats are tossed into the flume as they are shucked from the shells, and are carried by the stream of water onto a screen in another trough which runs along the dressing table. Jets of water in the second trough stir the clams and finally carry them to the end of the trough. The flume acts as a conveyor though it is primarily intended to wash the clam meats and free them from sand or other foreign objects.

Women handle the clam meats as rapidly as possible, snipping off the siphon and removing the dark body mass. Waste removed in dressing is dropped in gutters running along the edges of the table which carry the refuse to a drain. As the clams are trimmed and cleaned, they are dropped into quart measuring cups. The meats, if they are to be packed whole, are washed again before they are emptied into a trough on the packing table. They are hand-filled by weight into No. 1 picnic, No. 1 tall, or No. 10 cans. The cut-out (drained) weights required are 5, 8, and 36 ounces respectively.

The containers are filled with hot clam liquor and are sealed immediately. The temperature of the contents averages 160° F. at sealing so there is no need for heat exhaust or vacuum sealing. The process used varies with the packer as in many other products. Typical processes are, for No. 1 picnic cans, 20 minutes at 240° F. (10-lb. pressure); No. 1 tall cans, 70 minutes; and for No. 10 cans, 100 minutes at the same temperature and pressure.

Some butter clams are canned as minced clams. The dressed and washed meats are ground in a grinder with a ⅛-inch plate. The ground meats are discharged directly into a filler of the type used in packing minced razor clams. The cans are sealed immediately after filling. Other means of obtaining a vacuum are not necessary as the temperature of the contents at time of sealing averages 150° F. Representative processes in packing minced butter or little neck clams are, for ½-pound flats, 60 minutes at 228° F. (5-lb. pressure) or 45 minutes at 236° F. (8-lb. pressure). Minced clams packed in No. 1 picnic cans are given about the same processes.

Minced butter and little neck clams may have an attractive appearance if workmanship in packing is good, although the meat is somewhat darker in color than that of the razor clams. The texture is not as tender as that of minced razor clams, but the product has a strong clam flavor which is relished in clam chowder.

HARD CLAMS

The hard clam or quahog *(Venus mercenaria)* is found from the New England States to the coast of Texas. Hard clams are usually found below the low tide mark and do not burrow deeply into the bottom. They occur abundantly in the southern States where the most productive beds are found on the Gulf coast of Florida, in the vicinity of the Everglades region. The shells of the Florida hard clams are much thicker and heavier. Individual clams in the shell may weigh as much as 2 lb. but the meats are little, if any, larger than in the north. In the Middle Atlantic States hard clams are utilized in the canning industry only as an ingredient in packing "Manhattan Style" clam chowder.

Quahogs are taken by hand tongs and dredges of the same type used in gathering oysters. Hard clams are also gathered by "treading." The clammer wades about in water 3 or 4 feet deep pushing a light skiff. He feels for the clams with his toes, then picks them up by hand or with a short rake. Long-handled, specially designed rakes are used in some sections of the Atlantic Coast and ordinary shovels are also used at times.

Dredged clams are transported to the cannery in the holds of dredge boats. Clams taken by other gear are filled into wooden lug boxes or sacks and brought into the cannery by truck or boat. The distance between the clam beds and the cannery is usually not more than a few miles.

Upon arrival at the cannery, the clams are emptied on a chain-lug type of conveyor which carries them to a drum type rotary washing machine, set in a tank of water. The clams are whirled about and rinsed by water sprays under strong pressure to rid the shells of sand.

From the washer the clams are conveyed to strap-iron cars, such as are used in steaming oysters. The clams may be graded for size while on this conveyor, with those under $3\frac{1}{2}$ inches of shell taken off the conveyor to be canned separately as "little neck" clams.

The cars are run into steam chests, also like those used for steaming oysters except that provision is made for collecting the liquor lost by the meats in steaming open the shells. The liquor is piped from the steam chest to a collecting tank, where it is later filtered and added to the canned clams. It may be packed separately as "clam juice," "clam broth," or "clam nectar."

The steaming time and temperature used depends on the individual preference of the packer and may vary from 30 minutes at 212° F. to 15 minutes at 240° F. These periods are exclusive of the time required for "coming-up," and in "blowing-down" the steam chest. Steaming times are usually in excess of the minimum required to open the shell in order to obtain as much liquor as possible.

In some canneries the cars are sprayed with cold water as they are taken out of the steam chest in order that the clams may be handled as soon as possible, and to prevent toughening of texture. The clams may be dumped on shucking tables or the openers may work directly from the cars. Payment for shucking is on a piecework basis. One or two cuts of a short-bladed knife separates the base of the adductor muscles from the shell and the meat is dropped into a small bucket by the side of each worker. Usually no attempt is made to remove the dark body mass.

When the buckets are filled they are carried to a checker, where the meats are inspected, and washed in a weak 15° to 20° salinometer brine. A rotary washer may be used or the washer may be of the same type used in an oyster cannery. The washed meats are emptied on a conveyor belt which carries them to a packing table where they are hand filled into No. 1 picnic (Eastern Oyster) or No. 2 cans by weight.

A No. 1 picnic can is required to have a "cut-out" weight of 5 ounces; a No. 2 can, 9 ounces. To allow for the shrinkage in processing it is necessary to fill in an average of 15 percent additional. The packer should cut cans from each day's pack and determine the drained weight in order to vary the "fill-in" weight according to the degree of shrinkage in the meats. When filling, the meats may be graded according to size with small meat packed as "little neck" clams and larger sizes as "steamed clams."

The cans are filled with hot filtered clam liquor or if there is a good market for canned clam juice, a hot 3-percent salt brine is substituted. The cans are sealed immediately, without exhaust or mechanical vacuum. The process varies with the packer, but typical examples are: No. 1 picnic cans, 30 minutes 240° F. (10-lb. pressure) ; No. 2 cans, 45 minutes at the same temperature and pressure.

The pack is water-cooled after processing. Canned hard clams or quahogs are often variable in quality. Strong discoloration or "sea-weed" flavor and odor sometimes appear. These defects may be largely overcome by removing the dark body mass when washing the meat, but as this adds to the cost of packing it is not often done commercially.

RAZOR CLAMS

The razor clam *(Siliqua patula* Dixon) is found only on the Pacific Coast of North America, though related species are native to the Atlantic Coast of North America and northern Europe. The method of canning this clam was originated by P. H. Halferty in 1894. Razor clams are canned only in the Columbia River-Grays Harbor area of the Oregon-Washington coast, in the Queen Charlotte Islands district of British Columbia, in the vicinity of Cordova and at Kukak Bay in Alaska.

The shell of the razor clam is somewhat longer than the shells of the soft clam, quahog or butter clam. It is covered with a closely adhering brown membrane, which becomes darker in color as the clam increases in size, is brittle and has very sharp edges. The "razor-shell" clams of the Atlantic Coast are named for their fancied resemblance to the old fashioned straight razor, but the Pacific razor clam is so-called because the sharp edges are very liable to cut the digger's hands. The average size of the shell is 4½ inches long by 2 inches wide. These clams inhabit only hard sandy ocean beaches near low water mark, and the time in which they can be taken is restricted to a single brief period daily during the extreme low tide run out. The razor clams dig holes several feet deep in the beach sand, using the muscular foot as a digger. They come up near the beach level, with the siphon or "neck" at the top of the sand, so that water may be drawn in over the gills and the minute organisms forming their food may be strained out. When disturbed, the razor clams sink rapidly to the bottom of their holes and dig themselves in even deeper.

The razor clam is taken only by digging and each clam must be dug singly. Skill, strength and rapidity are required in digging, or the clams will escape. A short-handled long-bladed shovel, usually an irrigation ditch shovel with a cut down handle, is used in digging. Each digger drags a netting bag behind him attached by a length of rope. The clams are placed in this bag as they are dug, and are "surf-washed" by being dragged through the surf as the digger goes about his work. Production by the individual digger is small, not more than 2 bushels per day if experienced, the beach undepleted, the weather and tides favorable. Therefore, a large number of diggers are required to supply each cannery with raw material. The largest packer employed 1,800 diggers in 1938. Beaches on the Oregon and Washington coasts are quite long, as much as 18 to 20 miles to an individual beach, and as many as 1,000 diggers may be found working a beach at one time. In Alaska and British Columbia, the beaches are smaller and the area where clams may be taken is much more restricted.

The digger delivers the clams to a buying station maintained by the packer. Each lot of clams is emptied on an inclined wire screen of the type used by builders in screening gravel. The clams are inspected and graded roughly on this screen. Dead or broken-shelled clams are discarded, and undersized clams must be returned to the water. Regulations specify minimum sizes for razor clams and set penalties for taking under-sized clams. In Oregon and Washington no clam may be taken measuring less than 3½ inches.

After inspection the clams are transferred to wooden lug boxes holding approximately 75 pounds each, in which they are transported to the cannery. In Oregon and Washington the boxes are transported by motor truck. In Alaska and British Columbia clams are delivered at the cannery by boat, usually craft of the salmon cannery tender type. The boxes are piled in the hold of the cannery tender, or if the distance is short, the weather cool and the trip is made at night, they may be loaded on deck. Refrigeration is not used when transporting clams since it has not been found necessary. The distance between the cannery and the beach from which the clams are dug may vary from a minimum of 1 up to a maximum of 100 miles. The clams usually arrive in good condition even from the greatest distance.

In Oregon and Washington the canning season extends from March through May, with the peak of the season in late April. In Alaska packing is most active in late April and early May, although there is an autumn canning season in September and October.

On arrival at the cannery, the clams are unloaded onto a conveyor, passing through a heavy spray of water at a pressure of about 100 pounds per square inch. This spray washes the shells thoroughly, removing any remaining traces of sand from the shell and other portions of the clam reached by the spray. Carelessness in washing allows sand to get into the canned product, making it unsalable.

The washed clams are transferred to a type of steam chest, or hot water bath in which is placed an inclined screen pitched about 1 foot in 10. The surface, which is divided into a series of sawtooth ridges, is shaken by a cam mechanism. The clams are steamed or blanched for a minimum of 30 seconds to a maximum of 1 minute at a temperature varying from 209 to 212° F. The motion of the screen advances the clams from ridge to ridge and shakes the meats free from the shell after they have been opened by the steaming, or blanching in hot water. The clams must be cooled by a spray of cold water as rapidly as possible after steaming, otherwise they become quite tough in texture. Workmen standing by the side of the conveyor pick out the meats, freeing any still adhering to the shell. Meats are placed in shallow metal pans while shells continue along the conveyor, which carries them to a waste pile outside the building.

Women using medium-sized sharp-pointed scissors, specially treated to resist corrosion, dress the clams by cutting off the tip of the siphon and open the body from the base of the foot to the tip of the siphon (Fig. 48). The dark body mass or "stomach" is clipped off at the same time. The meats are then put through a washer built like the apparatus used in opening the shells, except that the meats pass through cold water at the end of the rocker where they are admitted.

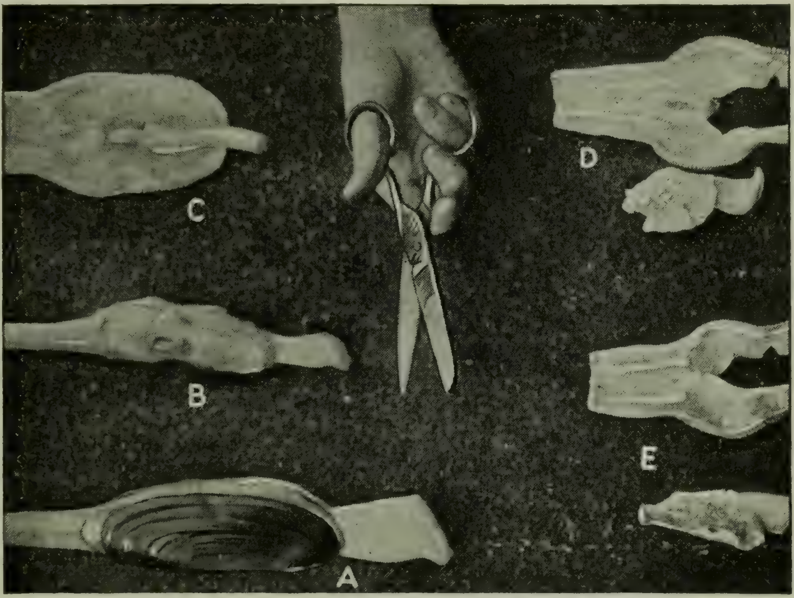

FIGURE 48.—Details of dressing and cleaning razor clams for canning. (A) As received at cannery. (B) Whole shucked clam. (C) After splitting. (D) After cleaning. (E) Ready for grinding. (Courtesy, G. P. Halferty)

After the meats are shaken and washed, a second group of trimmers remove the tough horn-like skin attached to the mantle, open up the foot or "digger," and scrape out the "liver" or other viscera from the body. The meats are given a third washing in the rocker washer and are then drained.

The drained meats are ground in a power-driven grinder with a ⅛ inch plate. Clam juice, obtained in steaming or made by boiling clam siphons and other edible trimmings with water, is mixed with the meat. The juice should be sufficiently hot so that the temperature of the mixture will be approximately 150° F. when filled into the containers. Empty cans are fed into a specially developed filling machine and filled at the rate of 40 per minute. The mixture in the filler tank is stirred to keep it from separating. Additional juice may be added if the mass is not sufficiently fluid.

Filling must be carefully supervised or the drained weight required by the U. S. Food and Drug Administration regulations will not be realized. Insufficient drained weight may be caused by an excess of liquid in filling or excessive shrinkage of the meats in processing. Over-processing increases the amount of shrinkage beyond the normal rate. Shrinkage in processing is believed to average about 25 percent, but varies during the season, becoming greater as the clams approach spawning condition. Variation in shrinkage also depends on the beach area from which the clams are taken. During the day the canner must occasionally cut cans after processing to determine the drained weight in order to make any necessary adjustments in filling. The regulations of the U. S. Food and Drug Administration require a drained weight of 3½ ounces for ½-pound flat cans, 5 ounces for No. 1 picnic, and 8 ounces for No. 1 tall cans.

The net weights usually declared on the labels are: 7 ounces for ½-pound flat; 10 ounces for No. 1 picnic; and 15 ounces for No. 1 tall cans. The difference between the drained weight and net weight is due to the liquid added when filling the cans. This liquid is clam juice, which is not only very palatable but possesses considerable food value.

In a few canneries the filled cans pass along a conveyor to a vacuum closing machine where they are exhausted mechanically and sealed. However, in most canneries the temperature of the can contents is depended upon to produce a partial vacuum and the cans pass directly from filler to double seamer. The sealed cans are stacked in strap iron trays which are loaded on small retort cars holding six trays.

There is no standard process in canning razor clams. Each packer uses processes determined by himself. Representative processes are, for ½-pound flat and No. 1 picnic or regular (Eastern oyster) cans, 70 minutes at 228° F. (5-lb. pressure); and for 1-pound tall cans, 80 minutes at the same temperature and pressure. Processes at high temperatures have been found to cause excessive shrinkage, with discoloration and overcooked flavor in the canned product.

Immediately after cooking, the cans are water-cooled in the retort. If the pack is not cooled rapidly, cooking continues, causing discoloration and loss of flavor. Packers also believe that slow air cooling causes toughening of the minced clam meat. The yield is given as approximately 20 No. 1 tall, or 40 No. ½ flat, cans per bushel of clams.

Some razor clams are not minced. The dressed and washed meats are filled into cans, so that a drained weight of 4½ ounces will be obtained after processing No. 1 picnic, or 7 ounces in No. 1 tall cans. Sufficient clam juice is added to fill the containers. The cans may be vacuum-sealed or the packer may depend on the hot clam juice to obtain a vacuum. The process given varies with the packer. No. 1 picnic cans may be processed for 45 minutes at 228° F. (5-lb. pressure) or 20 minutes at 240° F. (10-lb. pressure) ; No. 1 tall cans for 55 minutes at 228° F., or 25 minutes at 240° F. The pack is usually water-cooled after processing. The amount of whole razor clams packed is a small proportion of the total pack.

SOFT CLAMS

The soft clam *(Mya arenaria)*, also known as the long clam, mananose, or squirt clam, is taken commercially from Cape Hatteras northward, but is most abundant on the coasts of Massachusetts and Maine. Soft clams are canned only in these States, since they are not obtainable elsewhere in amounts and at prices at which canning is profitable. The soft clam season in Maine is fixed by law at September 15 to June 1. Canning does not start much before October 15, and is generally finished by January 1. Some canneries also pack in the spring, from late March into April.

The soft clam is found in mud banks and other tide flats covered with water at high tide. The clams have a long siphon or neck which makes it possible to burrow below the surface for a foot or more when the tide-lands are exposed. They vary from 2 to 4 inches in length, with shells which are rather smooth, thin and brittle in comparison with the quahog.

The only means of gathering is hand digging with spading forks, spades and hoes, or rakes of heavy construction equipped with several broad prongs. Dredges have not yet been adapted for harvesting soft clams. The presence of the clams is determined by the small holes in the sand, and the jets of water emitted when they are disturbed. The clams are tossed into buckets or other containers as they are dug or the clams may be dumped into a skiff and taken ashore at high tide. Production is limited since the tide flats may only be worked for a short time each day. A digger will bring in from 1 to 2 bushels of clams on a tide, depending on his skill and the degree of depletion of the digging area.

The clams usually are collected by trucks sent out by the canners. The clams are washed by the diggers and packed in burlap bags. The first operation at the cannery is to wash the clams thoroughly under a series of water sprays at heavy pressure. To remove sand and mud from within the shell it has been recommended that clams be held in tanks of circulating sea water until they have been freed of sand or other debris. This method is not used commercially as far as can be determined. Fresh or salt water may be used in washing, but salt water pumped near the cannery is apt to increase the amount of bacterial contamination.

The clams are graded after washing and any dead or broken specimens are culled. Little attention is paid to size and undersized clams are not returned to the beach. Clams fit for canning are placed in metal baskets and taken to a steamer. Steamers may vary from tanks equipped with a steam coil on the bottom and a rather loosely fitting lid, to processing retorts. In tanks the clams are steamed from 10 to 20 minutes. If retorts are used the pressure varies from atmospheric pressure to five pounds pressure. The time is not fixed but if the clams are used for bouillon as well as for meats, the steaming is heavier. A better plan is to turn on the steam for about two minutes which is sufficient to open the shells. The juice which has accumulated during this period is discarded since it consists of water held inside the shell and steam condensate. The juice collected from subsequent steaming contains a considerable quantity of extractives and after filtering is generally saved, to be used with the meats or for making bouillon or broth (Cobb, 1919).

When the clams have been sufficiently steamed the baskets are wheeled to the packing room and are piled on tables or benches, where workers remove the meats and prepare them for canning. The removal of meats is known as "snapping." The body muscles are cut from the shell and the dark body membrane is stripped away in one operation, after which the meats are rinsed. In order to remove the dark body mass the bodies are squeezed by thumb and forefinger. The siphons or necks are snipped off with scissors. The meats are again rinsed and dropped into pans. This work is generally performed by women and girls, on a piecework basis.

Some diggers steam open the clams as soon as they are dug. The equipment generally consists of an iron drum set over an open fire. The clams are removed after a few minutes heating, when the shells have opened. The digger and his family then remove the meats from the shells, and clean them in preparation for canning. The clam meats are then packed in slip cover tin cans of various sizes and held until the arrival of the cannery truck.

Several days may elapse between shucking and canning when this practice is followed. The quality of the canned product is adversely affected, and the bacterial contamination greatly increased, making it more difficult to secure a sufficient process. None of the larger packers or the more progressive of the smaller packers will accept clams shucked previous to delivery for this reason.

The pans of meats are taken to filling tables where packers fill the clams into the cans by hand, weighing the cans, or using scoops gauged to hold an amount sufficient to give the necessary drained weight. There is an estimated loss of about 15 percent in cooking or processing so that allowance must be made when filling the cans. The loss of weight in processing will vary with the degree of steaming before shucking, the shorter the period, the greater the loss, and to some extent with locality and season of the year at which the pack is made. It is estimated that 6 ounces of meats will be required for a 5-ounce "cut-out." The average yield of shucked clam meats, after removing "necks" (siphons) and "stomachs" (dark body mass), is estimated at 2 gallons per bushel. A gallon of clam meats should fill 24 No. 1 Eastern oyster cans, with a "cut-out" weight of 5 ounces each.

The cans are then placed on a conveyor belt which carries them under a perforated pipe which fills the containers with hot 3-percent salt brine. Some packers filter the liquor obtained from the clams in steaming, and add this to obtain a more pronounced clam flavor in the product. When brine is used as the filling liquid it is claimed that the appearance of the product is superior, with less trouble from darkening in the container.

Soft clams are packed in No. 1 Picnic, No. 1 Tall, No. 2 Short or special, and No. 2 Regular size cans. The No. 1 Picnic can is used more than all other sizes. The same process is generally given for all sizes; namely, 20 minutes at a 10-pound pressure (240° F.), but some packers process No. 2 cans for an additional 5 minutes. The cans are water-cooled immediately after processing.

The principal difficulty in the canning of soft clams is discoloration after canning. That this discoloration is not entirely due to the formation of iron sulfide is demonstrated by the fact that "C" enamel-lined cans tend to reduce but not to eliminate darkening. Unpublished data of experimental work conducted by the U. S. Fish and Wildlife Service indicate that blanching the clams for 1 minute in a 1.5 percent solution of citric acid at 180° F., and the addition of 0.5 percent of citric acid to the brine filled into the cans in packing, will inhibit darkening in soft clams without affecting the flavor of the product.

CLAM JUICE, BROTH OR NECTAR

In the process of opening all species of clams large amounts of liquid are extracted which contain varying amounts of soluble proteins and other food materials. Clam liquid is canned by methods which are usually quite primitive, although a few packers follow carefully developed canning formulae.

There is confusion as to nomenclature. Canning technologists agree that only liquid which is canned without dilution should be termed "clam juice;" that clam liquor diluted with water should be called "clam broth;" for example, liquor obtained by boiling clam trimmings in water, and only liquor concentrated by evaporation is "clam nectar."

The method most extensively followed is to strain the liquor obtained in steaming the clams through cheesecloth or similar material, filling it into cans or bottles while still hot and sealing the containers immediately. No two packers use the same process, and some still cook in the open hot water bath, believing that as the product is liquid, commercial sterility may be obtained at 212° F. This is not true as the liquid is apt to be more highly contaminated with spoilage organisms than clam meat.

Some packers pipe the liquor from the steamer to a storage tank, then to a mechanical filter, after which it is pasteurized for 3 to 5 minutes at 180° F., and is then filled into containers and sealed immediately. Clam liquor is packed in tin containers as follows: 8Z short, 8Z tall, No. 1 picnic, 1 lb. tall, No. 2, No. 2½, and No. 3 cans. Glass containers used are bottles with a crown type seal, splits, half-pints, pints, quarts, and half gallon jugs. The tin containers most widely used is the No. 1 picnic-size can; the glass container, the half-pint bottle.

Canned clam liquor should have a pearly opalescent color. A brown tinge is an indication of over–processing. Suspended solids sometimes collect into a flocculent mass at the bottom but this is not a sign of deterioration. The amount present depends on the degree of filtration.

Processes indicated to be sufficient by research studies by U. S. Fish and Wildlife Service are: No. 1 Picnic cans 45 minutes at 228° F. (5-lb. pressure), or 30 minutes at 240° F. The pack should be water–cooled immediately after processing.

MUSSELS

The Atlantic mussel *(Mytilus edulis)* is the only species canned in the United States and is also the variety used most widely in Europe. Other species such as *Modiolaria nigra*, are found in the same area but are not canned since they are usually smaller in size, differ in flavor and are more likely to be contaminated. The Atlantic mussel is commercially important only from Cape Cod to the Delaware River. It is found at depths from 1 to 60 fathoms.

Many are taken by pickers who scrape them from rocks on the shore, but dredges which resemble oyster dredges, although smaller, are also used in waters of the State of New York. The mussels are sorted for size and separated from undersized and dead mussels and debris such as pebbles, small stones and old shells, to which they are attached.

The catch must be landed within a few hours, and should be taken only from beds approved by the health authorities, as mussels are subject to extremely rapid decomposition, and are more liable to be the cause of food infections. (Tanner, 1933.) When the mussels are brought ashore they are cleaned of any seaweed clinging to the shells, and are freed from sand by a thorough washing in salt water. Any empty shells not removed in culling on board the fishing boat are discarded at this time.

The mussels are steamed at atmospheric pressure (212° F.) until the shells begin to open, which requires from 5 to 10 minutes. They are then emptied into pans or buckets and shucked. The byssus or "beard," a growth of horny filaments, by which the mussel attaches itself to rocks or other objects must be removed at this time.

The shucked meats are again thoroughly washed and held from 1½ to 3 hours in a 3-percent salt solution, to remove any remaining sand or grit from the meat and to give the proper salt flavor. The brine is drained off and the mussels then stand for 3 days in a 3-percent solution of distilled vinegar containing from 1 to 3 percent salt by weight. The pickling solution may acquire a bluish color during this time, but this does not affect the flavor of the product.

The next step is the preparation of a spiced vinegar sauce. To 4½ quarts of 6-percent distilled vinegar are added ½ ounce of bay leaves, ¼ ounce of white pepper, ¼ ounce of mustard seed, ⅛ ounce of whole cloves, ⅛ ounce of fennel and $\frac{1}{16}$ ounce of paprika. The spices are simmered, but not boiled, in the solution for 45 minutes. The spices are then strained out, the solution is filtered and set aside to cool.

The mussels are packed in 5-ounce glass tumblers or 8-ounce glass jars, after which the containers are filled with the spiced vinegar sauce, diluted one-half with water. In some instances the spiced vinegar sauce is used in the preliminary cure and a plain 3-percent vinegar is used to fill the jars. A portion of the pack is processed, but no accurate data are available on times and temperatures. Processing is said to vary from about 60 minutes in a hot water bath (212° F.) to 25 or 30 minutes at 221° F. (3-lb. pressure).

Non-processed pickled mussels remain in good condition from 2 to 4 months, depending on the degree of skill used in preparation and on temperature of storage. The pack must be protected from light, since the meats gradually darken if light rays are too strong. Storage at temperatures from 34° to 40° F. increases the "shelf life" of both processed and nonprocessed packs.

JELLIED MUSSELS

Some mussels are packed in jelly. Shucked mussel meats are pickled for 3 days in a 3-percent vinegar solution. One-fourth pound of best quality gelatine is dissolved in 2 quarts of hot water to which is added 3/4 ounce salt. When the gelatine solution is cool, it is mixed with 1 quart of spiced vinegar sauce diluted with 1 quart of water, and poured over the mussels packed in tumblers or screw top wide mouth jars. Jellied mussels are not processed and depend entirely on the pickling cure and on low storage temperature for preservation.

Mussel packs are prepared only in the vicinity of New York, Philadelphia and Boston, for sale to the delicatessen trade. Attempts to create a wider market have not been successful.

OYSTERS

EASTERN OR GULF OYSTER INDUSTRY

The oyster canning industry was first established on Chesapeake Bay, and for many years the bulk of the pack came from that locality, but today only one cannery is still in operation. Production in this area is irregular depending on the canned oyster market, and on the demand for fresh oysters. Raw material may come from any portion of the Chesapeake Bay oyster beds, and consists of "shell stock," sold to the cannery, if there is no great demand for fresh oysters.

Oyster canning has diminished greatly in importance on the South Atlantic Coast during the past 16 years. Tressler, (1923) listed approximately 38 canneries in North Carolina, South Carolina, Georgia, and the Atlantic coast of Florida. Not more than 7 or 8 canneries were still in operation in 1939.

The Gulf-of-Mexico area is now the principal oyster canning district, producing about three-fifths of the total pack. At present, more oysters are canned in Mississippi than in any other State, although production in the State of Washington approaches that of Mississippi. Biloxi, Miss., with 13 canneries, now has the title once possessed by Baltimore, the world's oyster canning center. Houma is the oyster canning center of Louisiana and most of the 5 canneries now operating are located in or near that town.

The oyster canning industry on the Pacific Coast draws its supplies almost entirely from Washington, principally from the Willapa Bay-Grays Harbor district. In contrast to the industry along the South Atlantic and Gulf Coasts, the oysters are obtained almost entirely from privately owned or leased beds which are "cultivated." The use of a "planted" or "cultivated" oyster in canning is practicable because the Pacific or Japanese oyster *(Ostrea gigas)* grows much more rapidly than Atlantic Coast species *(O. virginica.)* On the Pacific Coast, as is true in the Atlantic Coast, the cultivated beds are more productive; the oysters are usually taken in better condition and marketing is more orderly. The cultivation or farming of oysters is suggested as a method of improving the quality of oysters taken along the South Atlantic and Gulf coasts for canning purposes.

SECURING RAW MATERIAL

Tonging and dredging are used in gathering oysters for canning. Tonging is used in creeks or in other shallow water areas along the shore, usually where oysters are found in small and scattered beds. It is also used on the public domain, where dredging may be prohibited by law at certain times or within certain areas, as a conservation measure. Tongs vary in length from 12 to more than 20 feet, according to the depth of water in which they are to be used. They are long scissor-shaped tools with toothed iron baskets fitting together at the tips. The long wooden handles are an inch thick and 3 to 4 inches wide at the hinge point (about 4 feet from the end, but varying with the length of handle) and taper toward each end. They are riveted, bolted or pinned together. The toothed iron baskets which catch and hold the oysters are as much as 3½ feet long and 10 inches wide.

When the tonger is over a patch of oysters, he grapples the bottom until a cluster of oysters have been gathered into the basket, then lifts the tongs and shakes them out into the bottom of the boat. A single fisherman will average about 4 barrels of oysters a day.

The oyster dredge may best be described as a harrow with a single toothed bar, above which is a triangular iron frame to which a bag of chain or heavy rope netting is attached. The dredge is dragged over the bottom at the end of a tow line and the toothed bar scrapes loose the oysters from the bottom. As it is towed forward the loosened oysters are carried back into the bag. The dredge when filled is lifted to the surface by winch. In the oyster canning areas, both the number of dredges which may be operated by a boat and the size of the dredge, are limited by law. As a rule, a dredge may not be more than 6 feet wide and no boat may operate more than two dredges. In the States of New Jersey and Mississippi an oyster dredge cannot be operated by a power boat, so in these States when the boats are actually dredging they must be under sail. Boats may dredge oysters only when licensed for this purpose.

FISHING SEASON

The season during which oysters are gathered for canning depends on the condition of the oysters, the temperature, the demand for canned oysters and on legal restrictions. The length of the season has been reduced in recent years. It now runs from about January 1 to May 1 in all areas, but is changeable and may be altered by the state fishery agency. Few oysters are canned in the first and last portions of the season for the following reasons. If the oysters are still "thin" or "poor," the loss in packing would be increased, making canning unprofitable. If the weather is warmer than usual the reduced time in which live oysters may be held before spoilage takes place is a limiting factor. If the packers have a large sized "carry over" they are not apt to add to the over supply.

TRANSPORTING AND RECEIVING

The oyster dredges are drawn in over iron rollers fixed to the rail. Each of these rollers has another almost vertical roller at its after end, to guard against excessive wear of the dredge rope. As the dredge is being brought up it is raised and lowered through the water to give the oysters a washing which will remove some of the mud and sand. The dredges are emptied on deck and the catch is culled roughly to remove stones, dead shells and other debris, and the clusters are broken up to some extent, while another dredging is being made. Undersized oysters are replaced on the beds. The catch is then transferred to the hold.

The tonger also rouses the tongs about in the surface water, before emptying them into the boat, and culls his catch from time to time. The amount of debris to be culled in tonging is less than in dredging, since tongs are more selective in action.

On the Gulf Coast, oysters are usually canned in shrimp canneries. They usually are about 20 to 100 miles from the oyster producing areas. Oysters are much less difficult to transport than shrimp, and "shell stock" will remain alive from 2 to 5 days or longer if the weather is cool. Oysters are not usually unloaded immediately and placed in storage bins as for the fresh trade, but remain in the hold of the boat in which they were brought to the cannery until it is possible to pack them.

The method of unloading has not changed since early times. The bucket hoist is used for unloading the oysters from the boats to the canneries. The bucket is a heavy metal tub. It is hoisted by block and tackle attached to a swinging boom. The buckets of oysters are unloaded directly into the steaming cars which are strap iron wheeled crates on rails. These average about 8 feet long by 28 inches wide and 19 inches deep. Conveyors are only used in one or two canneries for unloading oysters. An oyster car usually has a capacity of 5½ barrels of oysters. In the oyster canning industry of the South Atlantic and Gulf States a barrel of oysters in the shell is equal to 4 U. S. Standard bushels of 2,150 cubic inches, or 4.95 cubic feet, except in Mississippi, where a bushel of oysters measures 2,826 cubic inches, so in that State a barrel of oysters is 3 U. S. Standard bushels, and the capacity of a car is estimated as 5 barrels. A car is the unit of count for payment to the fishermen.

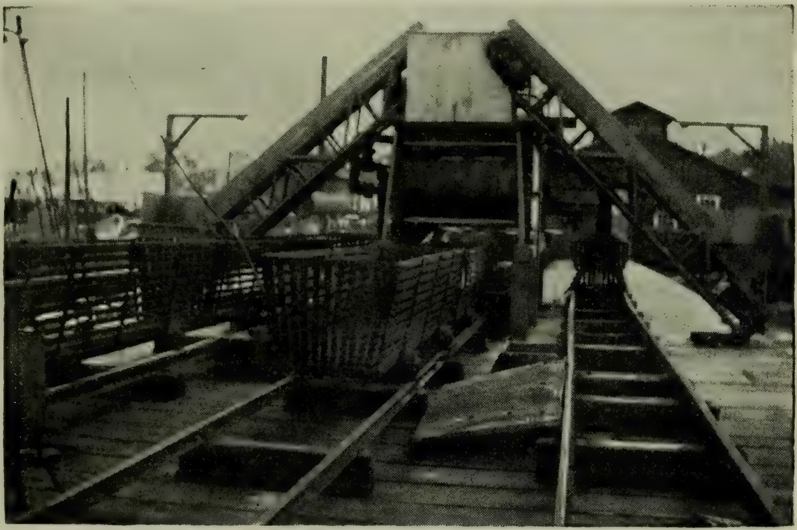

FIGURE 49.—Oyster washer for cleaning oysters before steaming and oyster cars used to hold oysters in steam box.

The oysters are not usually washed on unloading as it is claimed that washing is ineffective, and that steaming is much more satisfactory in cleaning the outside of the shell. One packer has recently installed a mechanical washer, and a few others spray the oysters with a hose after they have been loaded in the cars, but the practice is not widespread at present.

STEAMING

Loaded oyster cars are run along rails into a "steam box," a rectangular horizontal retort of sheet iron, with doors at each end. Steam boxes are often made of such light weight material and have been pitted with rust to such an extent that it is a wonder that they do not blow up under the steam pressures used. The steam chests have capacities of 3, 4, or 5 cars. The doors are usually fitted with wooden gaskets, which allow a good deal of steam to leak out after being used a short time.

The U. S. Food and Drug Administration (1937), recommended the following equipment for a steam box:

1. An adequately perforated steam inlet pipe running throughout the length of the bottom of the steam box.

2. A blow-off vent of at least 2 inches inside diameter in the top of the box.

3. A safety valve of at least 1 inch inside diameter in the top of the box.

4. Vents of at least ½-inch inside diameter in the top of the box not more than 1 ft. from each end of the box.

5. One-eighth inch bleeders in the top of the box not more than 1 foot from each end of the box.

6. A pressure gauge of a range from 0 to 30 lb. with scale divisions not greater than 1 lb. Such gauge shall be connected to the steam box by a short, gooseneck tube. The gauge shall be not more than 4 inches higher than the gooseneck.

7. An indicating mercury thermometer of a range from 170° F. to 270° F., with scale divisions not greater than 2°, in the top of the steam box.

8. Drains of at least 1 inch inside diameter in the bottom of the steam box, one at each end of the box.[15]

All steam boxes are equipped with pressure gauge, thermometer and some sort of drains in the bottom of the steambox, while some canneries use all the recommended equipment.

The oysters are steamed from 10 to 15 minutes at 245° F. (12-lb. pressure) the length of time depending on initial temperature, steam supply and to some extent the size and condition of the oysters. Some canneries steam from 6 to 10 minutes at 250° F. (15-lb. pressure). The periods given do not include the "come-up" or "blow-down" times. The "come-up" time is usually 6 to 8 minutes and "blow-down" time is 1 minute. The oysters must be steamed sufficiently to open the shell, and to permit the meats to be shucked without tearing the "eye" or adductor muscle. Poor steambox operation has been found to be an important cause of loss in oyster canning. Under-steaming seems to be a more serious problem than over-steaming, which does not appear to affect the flavor or result in excessive shrinkage. Under-steamed oysters may be torn, making them of a lower grade.

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[15] Food and Drug Administration, 1937. Tentative supplement to revised regulations for inspection of canned shrimp authorizing extension to oysters. 10 pp. Food and Drug Administration, U. S. Department of Agriculture, Washington.

The loss of raw material totals about 93 percent in oyster canning. This loss is largely shell, mud and the juice or nectar lost in steaming.

SHUCKING

The cars of steamed oysters are rolled into a shucking room, where the meats are at once removed from the shells by workers using a dull-edged knife with a small thick blade. Oysters must be opened while hot for clean removal of the "eye." The meats are shucked into small perforated metal cans holding from 8 to 10 pounds of meat. The shuckers in gangs of 8 work directly on the car. Shells are dropped on the floor to be shovelled into wheelbarrows for removal to the shell pile. A few canneries have installed conveyors to remove the shells but it is claimed that expense of installation and operation of a conveyor system makes the older method more economical in most canneries.

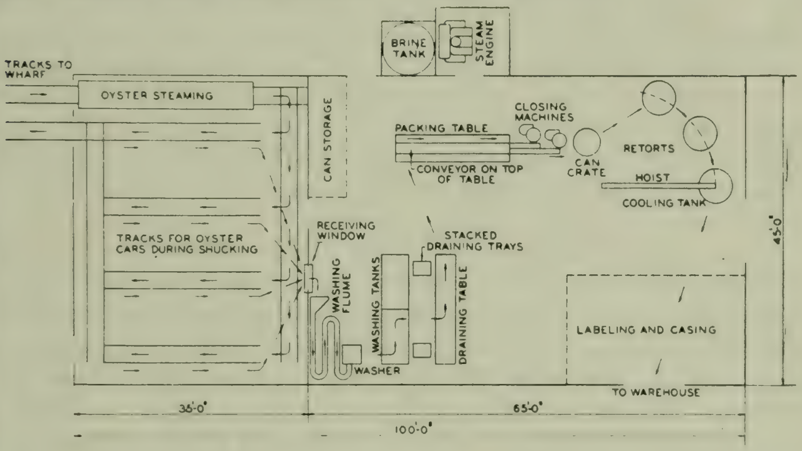

FIGURE 50.—Floor plan of typical Gulf oyster cannery.

Fifteen gangs of shuckers are needed to shuck 1,000 barrels of oysters in a 10-hour day. If the oysters are large, 10 gangs or 80 workers will be able to open this amount of oysters, but if they are smaller than usual it may take 18 gangs. The worker takes a full can of meats to a receiving window, where the meats are weighed and the shucker is paid immediately, usually 10 cents per can. Some canners inspect the meats for evidences of poor workmanship such as the inclusion of bits of shell or the presence of torn meats.

WASHING

After inspection the meats are emptied into a galvanized flume in which they are conveyed by cold running water to the washing tanks. A considerable quantity of grit and shell particles is washed from the meats and trapped by baffles fixed at intervals in the flume. The meats are washed from 20 to 30 minutes after which they are removed by dip nets and transferred to screen-bottomed metal trays about 24 by 18 by 4 inches in size. The filled trays are placed on tables where they are left to drain for 20 minutes.

INSPECTION AND GRADING

While draining, oyster meats are inspected and discolored, torn or otherwise defective meats are removed. According to the American Can Company, oyster canners on the Gulf Coast do not usually grade for size,[16] although packers segregate certain packs made with loads of oysters which are noticeably large or small. Oysters classified as large usually average 4 to 5 steamed meats per ounce while small oysters average 9 to 12 meats per ounce. They report that practically all oysters canned on the Gulf are classed as standards although some selects are packed. Terms such as "counts" and "extra-selects" are not used for Gulf canned oysters. Others terms designating quality characteristics are "fat," indicating plump or well filled oysters which may be either large or small; "poor," indicating lean oysters, not filled out and which may also be either large or small. Oysters with large "eyes" or adductor muscles, are desirable and the size of the eyes is one measure of the quality of the pack.

FILLING

On the Gulf Coast, shrimp packing equipment is utilized in canning oysters. The trays of drained meats are taken to packing tables where one girl fills the cans to a certain level, which approximates the necessary fill-in weight. A second girl places each filled can on a scale, adding or removing a sufficient number of meats to bring it to the correct weight. As the oysters gain in weight during processing and storage, the amount of meats filled into the can will be somewhat less than the drained weight. The fill-in weight is usually 3½ ounces if the drained weight is to be 4 ounces, 4½ ounces if it is to be 5 ounces, and 9 ounces for a drained weight of 10 ounces. The fill-in weights are varied to a certain extent throughout the season, depending on the condition of the meats. Plain cans without inside enamel are used, and approximately 70 percent of the pack consists of No. 1 Eastern oyster (211 x 400) cans, with a drained weight of 5 ounces. The standard case consists of 48 cans of this size and fill.

Atlantic and Gulf coast oysters will yield an average production of 13 cans (5 oz.) per barrel measuring 4.9 cubic feet if the oysters are "thin" or "poor." The yield will be from 18 to 20 cans if the oysters are "good" and 20 to 24 cans if they are "extra good." The general average is estimated at about 20 cans per barrel.

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[16] American Can Co. *The Canning of Gulf Oysters.* New Orleans Research Department Memorandum. American Can Co., Inc., 8 pp., New Orleans.

Only 4 girls, 2 filling and 2 weighing, are required for continuous packing when the cannery is handling 1,000 barrels of oysters per day. Most canners use from 6 to 8 workers at the packing table and only can the meats intermittently as the can sealing and processing capacity is far greater than the steaming and shucking capacity.

EXHAUST OR VACUUM AND SEALING

As the filled cans are conveyed to the can sealing machine or double seamer they are filled with hot 1-percent brine from a perforated pipe. In some canneries a 35-grain salt tablet is dropped in each can, which is then filled with hot water. This is done to overcome the waste of salt where the brine spray is used. The cans are sealed immediately after filling and the vacuum obtained depends solely on the temperature of the added liquid. After sealing the initial temperature of the can contents is approximately 160° F.

PROCESSING

The cans are placed in the retorts as soon as possible for if the lapse of time between sealing and processing is too great, the canned product will deteriorate. Retort control equipment required in processing shrimp should be used when packing oysters. The average come-up time is about 3 minutes. Carelessness in bringing the retort up to the proper steam pressure, and in removing air, may affect the sufficiency of the process. Oyster canning processes given in publications on canning technology prior to 1936 are no longer followed since processes of greater sterilizing value developed through research studies have been generally adopted by the industry after that date.

Containers smaller than the No. 1 Picnic or 5-ounce can are now processed for 17 minutes at 240° F. (10-lb. pressure), or for 8 minutes at 250° F. (15-lb. pressure) ; No. 1 Picnic cans are processed for 18 minutes at 240° F. or for 9 minutes at 250° F. No. 2 Short (307 x 400) and No. 2 (307 x 409) cans are processed for 19 minutes at 240° F. or for 10 minutes at 250° F. Research laboratories of the canning industry suggest using processes at 250° F. in preference to those at 240° F. A short process at high temperature and pressure apparently gives a product of better texture and flavor. A come-down period of 1 minute is allowed at the end of the processing time, to bring the pressure within the retort down to atmospheric level.

COOLING AND WASHING

The retort baskets are lowered into small tanks where they are water cooled, until the temperature within the cans has been reduced to approximately 98° F. Alkaline cleaning solutions are not needed as oil or particles of the product do not collect on the cans during packing. The retort baskets are sometimes cooled under sprays of water. There is also a pronounced tendency toward cooling in the retort as is done in canning "wet pack" shrimp.

STORAGE, LABELING AND SHIPPING

The cans are dried and are stored for a few days before labeling. The majority of the packers code mark the cans, but code lots are not stored separately as yet. Labeling is usually done by hand as a slack time occupation, although some labeling machines are used in the larger canneries.

The drained weight of meats contained in the can is usually stated on the label rather than the net weight of the total contents, as the regulations of the U. S. Food and Drug Administration specify definite drained weights of oyster meats which must be packed in each size of can. That agency has recently expressed the opinion that inasmuch as the liquid in the cans is also used as food, it is advisable to state net weight or total contents, on the label, rather than drained weight or amount of solids. *This interpretation does not alter the drained-weight specifications, which are still in force.* Drained-weight declarations now used on the labels with corresponding net weights suggested to comply with Federal and State regulations are tabulated below:

Can size	Drained weight and packer designation of can size	Net and proposed label weight	
	ounces	*pounds*	*ounces*
211 x 212	3	0	7.0
211 x 300 211 x 304	3½	0	7.0
211 x 306	4	0	9.0
211 x 400	5	0	10.5
211 x 405	6	0	11.5
307 x 400	8	1	9.0
307 x 408	10	1	4.0
307 x 409	10	1	4.0
307 x 414	12	1	5.0

The No. 1 Picnic or Eastern oyster can is occasionally packed with a drained weight of 4 ounces, but solely for the export trade on specifications of the buyers and the drained weight is declared on the label. This pack cannot be sold in the United States.

EXAMINATION OF CANNED OYSTERS

When examining the canned product the first requirement is that the can should cut out to the proper drained weight. Color standards cannot be set, but the cans should not contain oysters obviously discolored or "specked" when packed. However, a fairly large percentage of Gulf oysters called "cock" oysters are naturally very dark colored. These oysters are not inferior and must be distinguished from discolored oysters.

The product should have a characteristic sweet odor and should not contain grit, sand or bits of shell. The liquid should be opalescent but not turbid. In old packs and with inferior oysters, the color of the liquid will be dark gray. The presence of one or two torn meats in a sample may be disregarded, but if they appear with any regularity, it should be regarded as evidence of poor workmanship in packing and an indication of inferiority. If the oysters are sold as "fancy" or "large" a 5-ounce No. 1 Picnic can should contain from 16 to 20 in number, if "choice," 20 to 30, and if "standard" from 45 to 60.

PACIFIC OYSTERS

OBTAINING RAW MATERIAL

On the Pacific Coast, all oysters used in canning are grown on beds owned or leased by the packers. The beds are "seeded" with oyster spat purchased from Japanese seed oyster-growers who specialize in that business. The Pacific or Japanese oyster *(Ostrea gigas)* is a different species from those found in this country. It is larger, more irregular in shape, has a pronounced dark fringe banding the edge of the mantle which is not found in American oysters, and shows very rapid growth in areas where water conditions are favorable and the food supply abundant. Other species of Japanese oysters are imported on a very small scale. Of these the Hiyushima oyster *(O. cucullata)* is the most important. It appears to be a good variety for canning purposes, possibly better than the Pacific oyster as it has a regular shape, is of medium size, and its flavor is good. These factors together with uniform light color, a minimum of dark fringe banding the edge of the mantle, and an absence of dark, mottled spots on exposed surfaces, decide the suitability of oysters as raw material for canning purposes.

The oyster spat is shipped from Japan in wooden boxes. Each box contains 700 oyster shells with an average of 15 seed oysters clinging to each shell. A box of seed oysters cost $3.50 C. I. F. Seattle in 1938 and 15 boxes of seed oysters are required to plant an acre of bottom. This quantity should produce an average of 40 bushels of oysters for canning. The seed is planted in alternate squares of about one-half acre each on two successive years to secure a more equal distribution of food for the growing oysters, and so that some oysters may be gathered each year. The seed oyster requires approximately 2 years to reach a size suitable for canning.

Each shell acts as the base for a cluster of from 10 to 30 half grown oysters after 1 year. Workers walk over the beds at low tide, breaking up the shell into small clusters of 3 or 4 oysters with a hammer and distributing them over the ground. The cost of cultivation is estimated at $1.50 per box of seed planted.

When the oysters are to be harvested, light scows are "spotted" over the area at high tide, and at low tide the pickers go over the bare ground gathering the clusters into bushel baskets which are emptied into the nearest scow. The cost of picking averages 40 cents per case of 48 one-pound talls. In 1938 pickers were paid at the rate of 5 cents per bushel. When the oysters are quite thick they may be gathered by tonging at high tide. The high cost of labor in gathering oysters by hand has resulted in attempts at dredging, which is cheaper, but is said to tear up the bottom to an undesirable extent. It is estimated that 80 percent of the oysters are gathered by hand.

TRANSPORTING AND RECEIVING

The loaded scows are towed to canneries nearby at high tide. At the cannery the oysters are shovelled into an elevator consisting of a water tight wooden trough in which runs an endless chain with wooden cross bars about 6 inches apart. As the oysters go up the elevator they are washed by a spray of water at a pressure of 50 pounds per square inch. The used water runs down the trough, washing off some of the mud before the oysters reach the spray.

The oysters are discharged directly from the elevator into a receiving bin on the wharf, with a capacity of 500 to 600 bushels of oysters. Some bins are lined with iron plate.

PRECOOKING

There are two systems of precooking, both differing from the method followed in the eastern oyster canning industry.

Batch process.—In the first method the oysters slide from the receiving bin into an empty steaming car halted below (Fig. 51). The loaded cars are pushed along the track to a steam chest, which is a cylindrical, horizontal retort of heavy construction with doors at each end (Fig. 52). There is a 4 inch drop in the grade of the track through the retort allowing the loaded cars to be pushed out easily when precooking is finished. The steaming cars used on the Pacific Coast are approximately 3 feet wide, 5 feet long, and 1 foot deep, and have a capacity of 8 standard U. S. Bushels. Steam chests are built in several sizes from a capacity of 3 to 7 cars.

There is wide variation in the time and temperature of precooking, depending on size and condition of the oysters, but also due to the preference of the individual canner. In one representa-

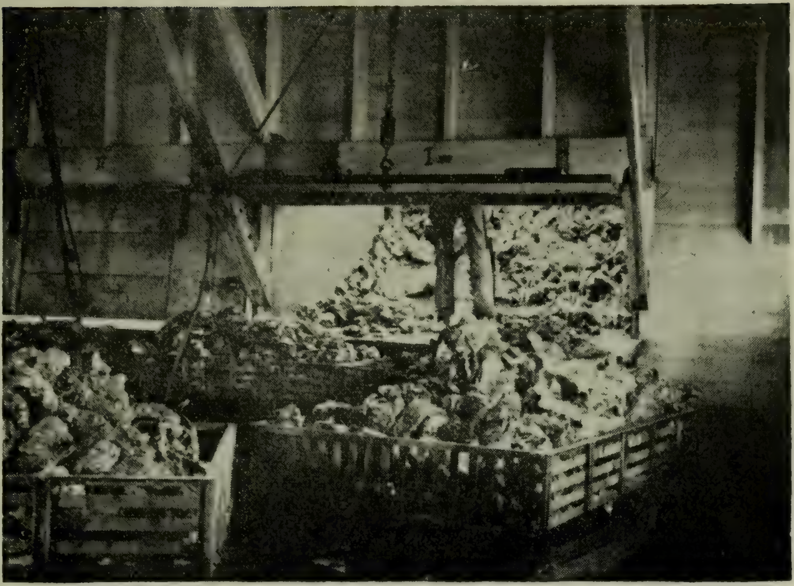

FIGURE 51.—Loading steaming cars of Pacific oysters from a receiving bin. (Courtesy, O. Wendt, H. Cron Company.)

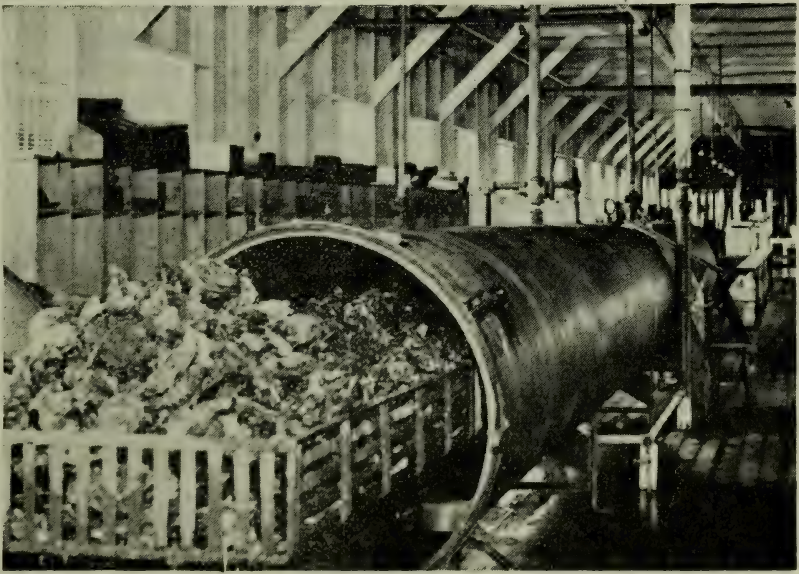

FIGURE 52.—Steamed Pacific oysters emerging from retort. (Courtesy, O. Wendt, H. Cron Company.)

tive modern plant, oysters are steamed from 3½ to 4 or 6 minutes at 240° F. (10-pound pressure). Other precooks used are 10 to 15 minutes at 212° F. (atmospheric pressure) and 5 to 10 minutes at 240° F.[17]

The shucking tables are large troughs in which the cars run on rails. There are wide ledges on each side, level with the top of the loaded cars. The oysters are shucked from the cars into 3-gallon buckets, which contain 1 gallon of water or 2- to 3-percent brine. The brine prevents crushing or bruising of the meats when they are placed in the bucket. Water or brine is also necessary to prevent oxidation of the meats, since the protective mucous coating of the oyster meat is destroyed in precooking, and the meats discolor rapidly if exposed. The method of shucking and the knives used are the same as in the Gulf Coast oyster canning industry. Shells are tossed into the trough, falling onto a conveyor below the tracks, which carries them to a shell conveyor outside the cannery.

Continuous precook. — In the second or continuous precook method, the oysters are conveyed from the washer, or storage bins, to a continuous cooker. Workers along the conveyor inspect the oysters and remove dead shell. The continuous cooker is simply a slat conveyor enclosed by a cylindrical or rectangular housing, which should be at least 12 gage galvanized iron, and insulated with asbestos.

According to McKee (1938) the slat conveyor which carries the shell stock through the cooker consists of two parallel chains, riveted pintle type, riding on angle iron rails on each side of the cooker. Wooden slats are bolted across, joining the two chains and forming the conveying surface. These slats may be of 1 by 2 inch material and 40 inches long, depending on the width of the cooker. A space between the slats of about ¼ inch, allows steam to circulate, and the slats may be perforated in order to provide additional circulation. Instead of the wooden slats, metal cross ties or bars may join the two side chains at 24 inch intervals and over these cross ties may be laid a chain link conveyor belt which has been woven from 12-gage wire with a ¾-inch mesh. This type of conveyor surface allows a maximum of steam circulation and is more sanitary as it permits more thorough cleaning.

Perforated steam pipes extend the full length of the conveyor both above and below, providing moist steam so that the oyster meats will not be burned. The cooker is supplied with dry heat by a series of unperforated steam pipes, also extending the full length of the cooker, with no outlet except a small "bleeder" valve at the lowest end. The maximum temperature in the cooker is not more than 210° F. The entrance and discharge ends are partially closed by means of a series of canvas baffles hanging from the top of the cooker. Clusters of oysters push the baffles aside which fall down into place again as the oysters pass.

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[17] American Can Co. The canning of Pacific (Japanese) oysters, Bull. Research Dept. 11 pp., 1 fig. Portland, Oregon.

The approximate length of the precooker is 75 feet and the average time required for precooking is 7½ minutes. When it is necessary to increase or decrease the rate of operation with change in the size of the oyster clusters, age of the oysters, or the ability of the shuckers to care for the output of the cooker, speed of operation may be altered by a variable speed device.

From the cooker the oysters are discharged onto a 12-inch wide steel opening belt which passes between two parallel rows of galvanized iron bins. The steamed oysters are plowed off the steel belt and into the bins within reach of the shuckers, who work at intervals about 30 inches on each side of the opening belt, opening the oysters on short boards placed across the bin in front of them. Shells are thrown through an opening under the steel belt falling on the lower or return half of the belt, and are carried to the far end where they are plowed off onto the shell pile conveyor. A 75-foot cooker with a 140 foot opening belt delivering to 30 shuckers on each side, will handle 4,000 bushels or more in an 8 hour day, depending on the size and condition of the oysters.

According to McKee[18] the advantages of the continuous system over batch precooking in retorts are:

1. Continuous flow of raw material.
2. Less labor is involved.
3. Less room is necessary and the whole process may be arranged in a straight line if so desired.
4. The loss through shrinkage is less.
5. The volume of raw material which can be handled is greater.

He reported the disadvantages of the continuous method of precooking as:

1. The first cost of equipment is higher since the installation of more machinery is required.
2. It is more difficult to remove the oysters from the shell, and more care must be taken to prevent cut and torn oysters since the oysters are not cooked so thoroughly.

WASHING AND GRADING

The shucked oysters are washed in a metal tank equipped with a perforated plate just above the bottom which is similar to the washer used for fresh shucked oysters. Compressed air is admitted below the false bottom aerating and agitating the wash water with which the tank is filled. Oyster meats placed in the tank are kept in constant circulation. Washing with this apparatus is a batch operation and the efficiency is at least partially dependent on the hand labor employed.

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[18] McKee, Lynne G. Personal communication to Norman D. Jarvis, 1938.

One packer has invented a special washer which works very effectively, is continuous in operation and is not so dependent on the cannery employees. It consists of a long shallow water tank through which a wire mesh belt conveyor travels near the surface of the water. Compressed air is blown through the water so that it is well aerated. The shucked oysters are emptied onto the belt conveyor and by the time they reach the discharge end any shell, sand or other debris is removed, leaving clean meats.

The oyster meats fall from the washer onto an endless white rubber grading belt of the type used in fruit canneries. Six girls act as graders, separating the meats into grade sizes and placing the oysters in large enamel basins as they are sorted. The grade sizes are usually large, medium and small, with the cut or damaged oysters as a fourth grade known as cuts or soup stock. Any dark or discolored oysters are discarded.

The best types of canning oysters are those which are round and fat. Round oysters pack into the containers more easily than elongated oysters and result in a better quality pack from the standpoint of appearance. Processed oysters which are too thin have a grayish-yellow color in the region of the livers.

FILLING

The packers count the oysters into the cans by hand (Fig. 53). The count per No. 1 tall can is usually 6 to 7 if the oysters grade large, 8 to 14 if medium, and 15 to 20 if small. The filled cans are weighed to insure a correct fill-in weight and an extra oyster is placed in each can to counter any excess shrinkage in processing. In contrast to Gulf Coast oyster canning methods, the greater part of the shrinkage occurs in processing, the amount of shrinkage varying according to the district from which the oysters were obtained, the condition of the oysters and the season. The filled cans pass under a perforated pipe and are filled with hot 2½- to 3-percent salt brine.

The usual range of fill-in weights used in canning Pacific oysters is: 7 to 9 ounces for a No. 1 Picnic (Eastern oyster) can with a cut-out (drained) weight of 5 ounces after packing; 10 to 13 ounces for a No. 1 tall can with a drained weight of 8 ounces; 14 to 16 ounces for a No. 2 can with a drained weight of 10 ounces. Regular cuttings should be made of each day's pack to make sure that the required cut-out weight is obtained.

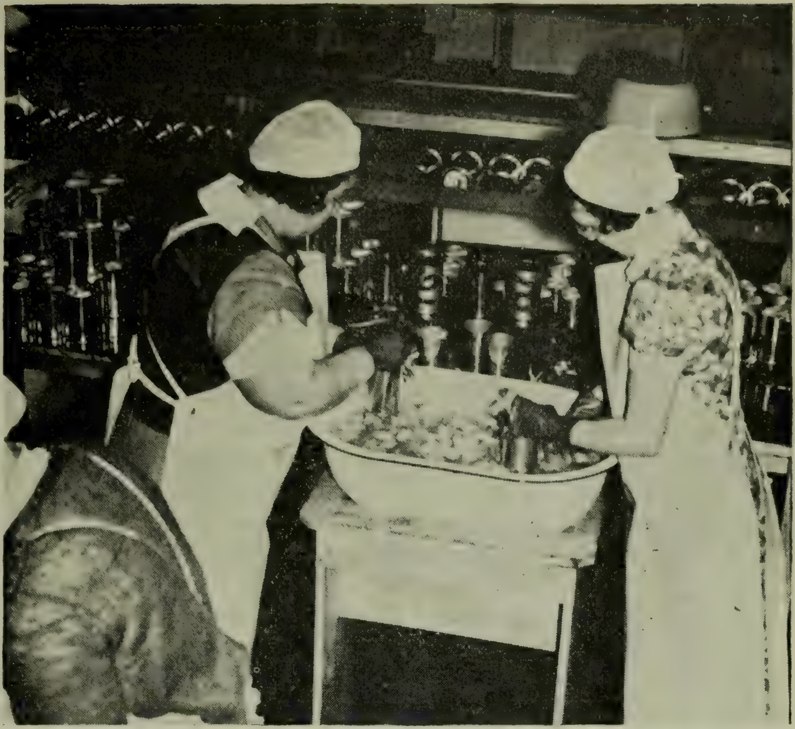

FIGURE 53.—Filling the cans with Pacific oyster meats. The oysters are counted into the cans which are then weighed. (Courtesy, O. Wendt, H. Cron Company.)

EXHAUSTING AND SEALING

The conveyor then carries the cans through a "clincher" which crimps the lids on lightly, and through an exhaust box where they are given a steam exhaust of 5 minutes at 208° F. Some packers seal immediately after brining. This is not considered a good practice as the vacuum obtained does not average much more than 3 inches, where it should be not less than 10 inches. The use of vacuum closing machines in canning Pacific oysters is particularly recommended by canning technologists, but these machines are not yet used to any great extent.

Regardless of the method of exhausting, the cans should be filled so that the solids do not protrude above the liquid level, since the exposed surfaces will acquire a brownish-yellow discoloration due to oxidation during the process. If a heat exhaust is used, cans may be filled entirely full of brine when the end is applied. If a vacuum closing machine is used, the cans should be uniformly filled with brine allowing from $\frac{3}{16}$- to ¼-inch headspace to insure a satisfactory vacuum being created in the can by the closing machine.

The cans of oysters are discharged from the exhaust box onto the conveyor of a closing machine, which completes the seal. The sealed cans are stacked in salmon "coolers" which are loaded on trucks and taken to a horizontal retort.

PROCESSING

Representative processes used in canning Pacific oysters are: No. 1 Picnic (Eastern oyster) cans, 20 minutes at 240° F. (10-lb. pressure); No. 1 talls, 35 minutes, and No. 2 cans, 42 minutes at the same temperature and pressure.

COOLING, WASHING, AND STORAGE

The pack is water-cooled in the retort by heavy sprays from perforated pipes. It is usually allowed to stand at least two days in the warehouse before labelling and casing. Practically all of the canned Pacific oysters are coded, but the code is not as elaborate as those used in salmon or shrimp packing, usually consisting of a letter and two figures. The labels are similar to those used in the Eastern oyster canning industry in design but are modernized.

The cans used are not lacquered but have outside enamelled ends. A lining of "C"-enamel, seafood formula, is also recommended to avoid discoloration of can and contents through the formation of metallic sulfides. The methods of storage and examination of the canned pack are similar to those used in the Atlantic and Gulf Coast oyster canning industry.

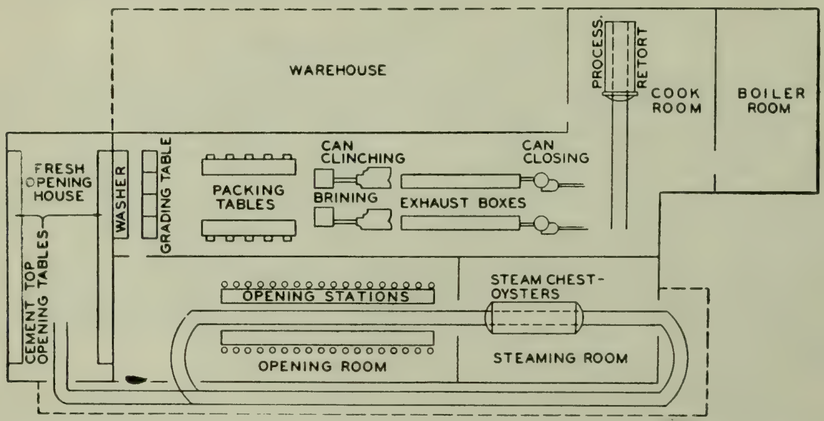

FIGURE 54.—Floor plan of a Pacific oyster cannery. (Courtesy, American Can Company.)

SMOKED OYSTERS

Smoked oysters, packed in "quarter oil" sardine cans have been imported into this country for some years. However, a method of smoking and canning oysters has recently been developed by packers of Pacific oysters in the State of Washington.

Smoked oysters are strictly a specialty product and are sold as an appetizer. Pacific oysters are used which have not attained normal growth in the first 9 months to 1 year after planting, due to adverse growing conditions. Medium-sized Pacific oysters may be used if the pack is to be fancy-grade. Experimental packs of canned smoked oysters have also been made with oysters too large for the commercial processed oyster pack and these are cut into pieces 1½ to 2 inches square prior to smoking. However, no commercial packs of cut smoked oysters have yet been made.[19]

Smoking.—The washed and drained oyster meats are placed in heavy galvanized wire mesh bottom trays. Only one layer of oysters should be placed in a tray, spread so that the smoke can penetrate uniformly. The wire mesh should be oiled with lard oil or a tasteless salad oil before use to prevent the meats from sticking. The filled trays are stacked 5 or 6 deep on fixed racks inside the smokehouse though movable racks may be used.

The smokehouses used for smoking oysters are of the same general type as for smoking salmon. They consist of a lower story, 8 to 10 feet high, sometimes called the "fire pit," in which the fire is built, separated from the upper story, usually from 8 to 12 feet high, by a grid of iron, which serves as a place for the workers to stand in loading and unloading. Drafts in the fire-pit door, and movable louvers in the top of the upper section provide for circulation of smoke. The smokehouse may be of brick, concrete or heavy galvanized iron construction but use of the last is not recommended as humidity and temperature are more difficult to control.

Crab-apple wood is preferred for smoking, but any hardwood should be suitable. A low fire is built down the center of the fire pit floor and allowed to burn with a clear flame for 1 to 2 hours, until the oyster meats have dried. The fire is then partially smothered so that a fairly dense smoke is obtained. The meats are cured in this smoke for 3 to 4 hours. If they are to be canned, oyster meats should not be smoked until dark and hard, because a light cure is regarded as producing a more appetizing product both in flavor and appearance.

Filling.—After cooling, the meats are filled into ¼-pound salmon cans by hand. The amount of oysters placed in each can is 2¼ ounces by weight or 4 to 6 meats by count. Approximately ½ ounce of edible vegetable oil is added to each container.

Exhausting and closing.—Either heat exhaust or vacuum closure may be used to produce a vacuum which should be not less than 9 inches. If the cans are heat exhausted in a steam exhaust box, the covers are clinched on loosely before containers enter the box. Five minutes at 209° F. should be sufficient for this style pack. Canning technologists recommend use of a vacuum closing machine in place of a thermal exhaust but so far as is known it is not used in the commercial canning of smoked oysters to date.

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[19] American Can Co. Canning of Smoked Pacific (Japanese) Oysters. Bull. Research Department 9 pp. Portland, Oregon.

Processing and cooling.—The sealed cans are stacked in salmon coolers and taken to the retort for processing. A process of 60 minutes at 240° F. is used in commercial practice. The pack is water-cooled in the retort to a temperature of 100° F. by a spray cooling system and is usually allowed to stand 48 hours before labeling and casing.

SQUID

In the United States squid are canned only in the Monterey Bay area of California. The pack is small but is increasing in size, with the most important markets in the Philippine Islands and in California. The Chinese and people of Latin or Greek descent are the principal consumers of canned squid in California.

The only species canned is the common squid *(Loligo opalescens)* of the Pacific Coast, which has an elongated, pointed body, with triangular fins near the posterior end. The range of this squid is from Puget Sound to San Diego. While a few squid are caught throughout the year the period from about April 1 to June 30 is considered the regular squid fishing season.

The fishing area is almost entirely within the limits of Monterey Bay, with the waters off Moss Landing and Watsonville as important catching areas. Sardine nets such as half-ring nets are probably used most widely, with some lampara nets and a few purse seines. Like sardines, the schools of squid can usually only be located at night in the "dark of the moon," by the phosphorescence of the water resulting from their movements. The only distinction in locating squid rather than sardines, is that the former species causes a "fluttery" or "wriggly" phosphorescence in the water while for sardines it is more or less in straight lines.

The squid are landed at Monterey within 2 or 3 hours after catching, so that no special care in handling is required. They cannot be unloaded by the sardine pumps at the canneries, so are unloaded at the fresh fish market dock. The squid are unloaded into wooden fish boxes which are transported to the cannery by truck or they may be piled loose in a deep truck body.

At the cannery the squid are transferred to storage bins, from which they are removed as required. The method of handling depends on the style of pack which may be either "with ink" or "in oil." If the squid are to be canned "with ink," that is, without removing the sepia bag, they are simply washed thoroughly and are not eviscerated. If they are to be canned "in oil," they are washed and dressed, removing the sepia bag.

For precooking, the washed and drained squid are piled in thin layers in sardine frying baskets, 18 inches square and approximately 6 inches high. If the cannery is equipped for tuna canning, the baskets are trucked into tuna cookers; if not, they are placed in the processing retort and are given a precook of 45 minutes at 216° F.

After precooking the squid are cooled for about 2 hours and then taken to packing tables to be filled into containers. Three sizes of container are used, No. 1 picnic, No. 1 tall, and ½ tuna cans. Girls fill the squid into the first two sizes "asparagus style," that is, vertically. Squid packed in ½ tuna cans are coiled in horizontally. A No. 1 picnic or 9 ounce can as it is called locally, should hold 3; a No. 1 tall, 4; and a ½ tuna, 2 squid. The first two sizes of cans are used when packing "with ink" while squid in ½ tuna cans are packed only in oil.

The filled cans travel by conveyor to the exhaust box. If squid are being packed in oil, a girl stands by the conveyor and pours 2 ounces of cottonseed oil into each can. The cans are exhausted without lids for 20 minutes at 210° F. Then the tops are placed on the cans and they are sealed by a double seamer.

The processes used are: No. 1 picnic and No. 1 tall cans, 75 minutes at 240° F. (10-lb. pressure), while squid in ½ lb. tuna cans are cooked 55 minutes at the same temperature and pressure. The cans are washed after processing and allowed to air-cool.

RAW PACK

The "raw pack" method was formerly used most widely in canning squid and is still followed by some packers. The raw squid are washed thoroughly then packed into ½ tuna, No. 1 picnic or No. 1 tall cans with fill-in weights of 8, 10 and 16 ounces respectively. The filled cans are exhausted for 15 to 17 minutes at 208 to 210° F. in a steam exhaust box. The exhausted cans are filled with hot 3 percent salt brine from a perforated pipe. The cans are then sealed, run through a can washer and given the same process as precooked squid.

CRUSTACEA

CRAB

Three species of crab are canned commercially in the United States and its territories, the "Dungeness" crab *(Cancer magister)* or common crab of the Pacific Coast; the "king," "deep-sea" or "Japanese" crab *(Paralithodes camtschatica)* taken in Bering Sea and the Gulf of Alaska, and the "blue crab" *(Callinectes sapidus)* or the common crab of the Atlantic Coast. Successful commercial canning of the latter varieties is a very recent development.

DUNGENESS CRAB

The Dungeness crab is taken as far north as Unalaska, but the commercial fishery in Alaska is confined to Southeastern and Central Alaska with Petersburg and Cordova as the two important producing centers. The Dungeness crab is fished commercially as far south as northern California, but is canned only at Marshfield and Newport, Oregon, Pillar Rock and Willapa Harbor in the State of Washington.

This species is much larger in size than the common or blue crab of the Atlantic Coast, some specimens measuring 9 inches across the back shell. It is illegal to take crabs measuring less than 7 inches across the widest part of the shell, under existing Alaska fishery regulations. Minimum size limits of 7½ inches are also fixed under the laws of the States of Oregon and Washington.

The crab fishing season in Alaska opens late in March, the date depending on weather conditions. Catches are light at this period, and the fishing is not at its best until warmer weather arrives about May 1. Fishing continues until December 1, but production slacks off about November 1. Alaska fishery regulations establish a closed season in which crab fishing is prohibited; which varies in the different fishing districts, but extends over a period of about 6 weeks when the crabs are soft and inferior.

Crab fishing is carried on during all seasons of the year in Oregon and Washington, but production is lightest in winter largely due to weather conditions. The canneries obtain most of their pack in summer months when prices for fresh crab are low. Fisheries regulations do not at present require a closed season in either Oregon or Washington.

The fishing method used most extensively in catching the Dungeness crab resembles Atlantic Coast lobster fishing in many respects. Traps are used, oblong and boxlike in shape, and the usual dimensions are 3 by 2 feet, with a depth of 15 inches. The framework is made either of half-inch iron rods, or 1-inch strap or angle iron, and is covered with a heavily galvanized wire mesh. Into the two ends of the trap are fitted funnels of tarred cotton webbing, each fastened to a ring 6 inches in diameter at the inner end. The crabs enter sideways through these rings.

The trap is baited and the catch removed through a hinged door in the top. At each corner of the top is fastened an end of 6-thread steam-tarred bridle line running to a point about 2 feet above the center, where the lines are united and end in a loop. A buoy line ending in a wooden float is attached through this loop. Bait, either clams or fresh scrap fish, is placed in a webbing bag, hung in the center of the trap.

Details of fishing methods, transporting, and receiving are descriptive of the industry in Alaska. Methods differ to some extent on the Oregon-Washington coast, but the industry is largely centered in Alaska. The fishing is carried on at depths of 6 to 15 fathoms, and the traps are set at distances of 150 to 300 feet apart, depending on such condition as probable abundance of catch and nature of bottom. Small power boats equipped with a boom and power gurdy are used to set and haul the traps.

The tender picks up the buoy of the first trap on the line, and drops a previously baited trap nearby. The buoy line of the first trap is run through a block hanging from the boom, and is attached to the power gurdy, by which it is lifted to the surface and hauled inboard. On the way to the next trap, the crew of the tender remove the crabs and re-bait. This trap is then dropped by the second trap and the process is repeated until all the traps have been lifted. It is said that a crew of two skilled fishermen can handle a string of 150 traps a day, if the fishing grounds are good and weather conditions are favorable. Canners estimate that this number of traps, set on good fishing grounds, should furnish an average catch of 1,500 crabs per day. The catch is much less of course at the beginning and end of the season, if the bottom is not good, or if fishing conditions are unfavorable.

At the end of the day the fishermen take their catch to a live box anchored near the fishing grounds. The live box is a shallow crate, of no set dimensions, hung between two logs which act as floats, and is built of three-inch slats spaced two inches apart to permit a free circulation of water. The live crabs can be held in good condition for several days or even longer.

The live crabs may be taken to the cannery by a pick-up boat, calling at regular intervals, or the fishermen may use their own boat when enough crabs have been accumulated to make a load. Dungeness crabs are able to live out of water for several days if

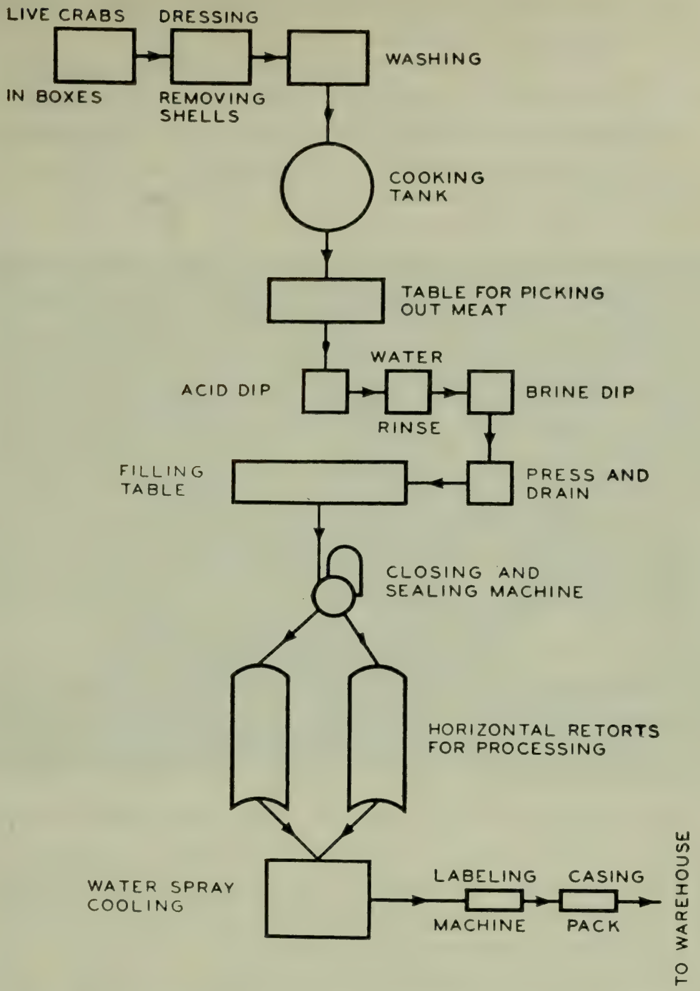

FIGURE 55.—Flow sheet illustrates procedure in canning Dungeness or Pacific crab.

kept cool and damp but die quickly in warm weather or if left in the sunlight. They are loaded into the hold of the boat where they are sprayed occasionally by a salt water hose. In cloudy cool weather a deckload may be carried. In this event, an awning is rigged above the deck and the crabs are kept sprayed with salt water.

The crabs are generally landed at the cannery in the late afternoon or evening. They are unloaded into large boxes which are hoisted to the cannery dock, where they are left until morning or if the catch is larger than can be packed during the next day, the surplus is placed in live boxes. While the crabs are still alive in the morning, they are not as lively as on landing and are handled more easily. As a general rule, the fishermen are paid a flat price per dozen crabs regardless of size.

The crabs are taken to cleaning tables where a workman removes the back shell or carapace, by hooking the edge of the shell over a stationary hook and giving a sharp jerk. Another workman then cuts each crab in half by bringing the body down across a large knife blade fixed to the table. The viscera are removed and the body of the crab is thoroughly washed in a jet of fresh clean water under considerable pressure. This water is warmed sufficiently so that the hands will not be numbed in washing the crabs.

The cleaned and washed portions are taken to large cooking tanks filled with fresh water heated by live steam. In some canneries, sodium bicarbonate is added in the proportion of ½ pound to 40 gallons of water. This practice is not recommended and should be abandoned. It serves no useful purpose, increasing the natural alkalinity of the crab meat and neutralizing the effect of the acid dip given later in the packing operation. The crabs are dumped into the tanks of boiling water and are cooked for an average period of 20 minutes.

Some packers precook the crab in a steam chest for about the same length of time at a temperature from 212 to 220° F. More of the flavor of the meat is believed to be retained by this process, but packers who use the boiling-water cook claim the meat is more readily picked from the shells.

The crabs are given to the pickers immediately after cooking as the meat is removed more rapidly and completely if picked before the crabs have cooled. In picking, the workers break the shell on the legs with a small wooden mallet, then pound the shell of the body against the pan in which the meat is to be picked, which loosens and releases the meat without breaking it into small flakes. Body- and leg-meat are kept separate and about equal proportions are obtained of each. Unlike the crab meat of the Atlantic Coast, the leg meat is considered as the higher grade.

The picked meat is dipped in a dilute acetic acid solution for about 1 minute. This solution is made up in the proportion of 2 ounces of 28-percent acetic acid to 1 gallon of water. Following this treatment it is washed in fresh water and dipped in a 100° salinometer brine. The meat is then pressed to remove excess moisture, drained and taken to the filling tables.

Dungeness crab is packed in cans of three sizes, "half flats," "pound flats" and "No. 2" cans, with net weights of 6½, 13 and 17 ounces respectively. All cans are lined with "C" enamel, seafood formula, and a lining of vegetable parchment paper is inserted before filling as an added protection. Hand packers fill the cans with a layer of leg meat on the bottom, top and sides, while the center is filled with body meat (Fig. 56). About 1/4 ounce of salt is added to each can.

The trays of filled cans are sealed in a vacuum closing machine. The sealed cans are packed in salmon coolers and processed. There is some variation in processing, but all packers agree that it must be closely controlled, and that steam pressures around 10 lb. have an adverse effect on the color of the crab meat. Representative processes now in use are: Half flats 90 minutes at 221° F. (3-lb. pressure); and for 1-pound flats and No. 2 cans 80 minutes at 228° F. (5-lb. pressure). The cans are cooled by a water spray system upon removal from the retort. When the cans are thoroughly cooled and cleaned they are labeled and packed in wooden or fiberboard cases holding 96 half flats, 48 pound flats, or 24 No. 2 cans.

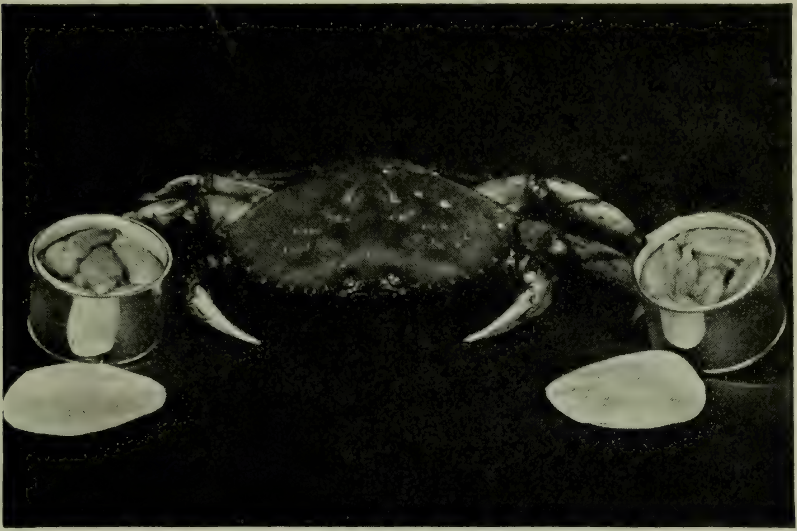

FIGURE 56.—Dungeness crab and cans of crab meat showing method of filling.

KING CRAB

The United States fishery for king or deep sea crab is carried on off the coast of Alaska, mostly in the Bering Sea, with the Port Moller district as a favorite fishing area, but also to some extent off False Pass on the Pacific side of the Aleutian Islands and in the vicinity of Port Alitak. The king crab has been taken experimentally along other portions of the Alaskan coast, but is not fished commercially in these areas as yet. The fishery off the coast has been conducted by Japanese floating canneries but a domestic canning industry has been created within the last few years.

The king crab has a moderately sized body with extremely long legs. Some specimens may measure as much as 6 feet from tip to tip of legs, though the average range in size is from 3½ to 4 feet. It is estimated that the meat from one leg is equivalent to the contents of two 1-pound cans of crab meat.

The king crabs taken by the Japanese floating canneries are caught in anchored gill or "tangle" nets. These nets, made of tanned cotton twine, measure approximately 150 feet along the lead line, 165 feet along the cork line and 81 feet deep, according to data collected by the Fish and Wildlife Service. Japanese sources agree as to the length but give 10 feet as the depth. Japanese regulations call for a minimum legal net mesh of 18 inches, stretch-measure. Glass buoys, 5 inches in diameter, are used in place of floats or corks. They are enclosed in a net-like casing of manila fiber and are attached to the cork line by a short length of manila line. Bower (1931) reported that the buoy ropes are 30 to 50 percent longer than the depth of water, thus preventing the net from hanging as a vertical wall in which the crabs would not become entangled. Rocks are used as leads and one sinker is used to each float.

The nets are set and hauled from "Kawaskisen," open fishing boats of Japanese type about 9 foot beam, 45 feet in length, and equipped with a 10 horsepower semi-diesel engine. Each boat carries 500 nets, with a crew of 8 or 9 men, and from 4 to 10 boats are operated from each floating cannery.

The boats select a favorable fishing ground and set the nets. These are not anchored singly, but are attached to each other in gangs or lines of 20 nets, though longer strings may be operated. The fishermen first set out an anchor, with a large marker buoy, then pay out the nets, usually in a line parallel to the shore or with the current or prevailing wind. The end of the last net is anchored and marked by a flag and marker buoy. Fishing is carried on at depths of from 20 to 50 fathoms. The total amount of net fished at each set is estimated at from 10 to 14 miles. After all the gangs of net are set out, the fishing boats return to the cannery ship. A period of from 3 days to a week is allowed before hauling the nets, depending on weather and probable abundance of catch. Experimental studies by the Fish and Wildlife Service indicate that the otter trawl may be a more efficient type of gear than the tangle net, or small trap which is also used to some extent.

The fishing season has not yet been determined accurately in the domestic fishery, owing to the very recent development by United States interests. Japanese reports give a fishing season extending from April to September on the Alaskan coast, with the peak of production in late May and June. American interests have operated from April until late in November and state that the peak of production is in the fall and winter months, with very light catches from June to October.

With a single exception, floating canneries are used by all canners, both American and foreign, on the coast of Alaska. These are factory ships entirely self contained, moving from one part of the coast to another as fishing conditions dictate, while the catch is both canned and stored on board the ship which transports its own production back to the home port.

As soon as the crabs are landed on the cannery ship, they are dismembered. The back shell is torn off, the viscera and other waste portions are removed and the portions to be utilized are washed and thoroughly cleaned. Butchering and cleaning before precooking is an important point in the method for canning king crab. If the butchering and cleaning were not done until after cooking as is the practice in preparing fresh cooked crab meat on the Atlantic Coast, a much longer period would be required, thereby increasing the possibility of discoloration in processing. Research data indicates that cooked crab meat deteriorates in quality much more rapidly than uncooked meat and is also more difficult to clean (Oshima, 1931).

The cleaned portions are placed in large wire baskets which are lowered into tanks of boiling salt water and cooked from 10 to 20 minutes. Immediately after the precook, the baskets are plunged into cold water in order to cool the meat to a stage where it can be handled promptly. The crab is then taken to cutting tables where the leg, claw and body meat are separated from shell and tendons and piled in baskets according to grade.

Four grades are used in sorting the meat. The meat obtained from the first segment of the legs is classed as fancy; leg meat of smaller sizes make up the second grade; broken pieces of leg meat comprise the third grade, while the body meat is considered as fourth grade and lowest in quality. The graded meat is washed thoroughly and picked over to remove any remaining fragments of shell, tendon, partially cooked flesh or other offal. The washed meat is allowed to dry on trays, each containing a single grade. When thoroughly dry the meat is delivered to the "cutters" who trim the pieces to fit the cans.

The crab meat is packed in cans known as "quarters," "halves," and "ones," with fill-in weights of 3½, 6½ and 13 ounces respectively. Most of the crab is packed in "halves." The cans used are inside enameled with "C" enamel, seafood formula, and are lined with vegetable-parchment paper. Foreign packers use either a three-piece lining or the ordinary one-piece lining. American packers use a special parchment-paper cup designed to fit the can.

The largest pieces of leg meat are laid out in a layer on the bottom; a layer of body meat is filled into the center and is followed by a top layer of leg meat followed by about 1/4 ounce of salt. Under conditions where the pH of the meat has been increased between catching and cooking, or cooking and canning, or where there is a possibility of discoloration, about 20 cc. of a weak solution of organic acid, either acetic, citric, lactic or tartaric is added to each half-pound can.

The covers are clinched loosely and the cans are given a steam exhaust of 7 to 10 minutes at 200 to 212° F. Sealing is completed by a can closing machine as the cans emerge from the exhaust box. Vacuum closing machines are also coming into use.

Immediately after sealing the cans are piled in trays and are then processed. Information differs as to the process to be recommended, but it is agreed that a process too high in temperature or too long in time will affect the color and flavor of the product. The processing of "half-pound" cans may vary from 90 minutes at 221° F. (3-lbs. pressure) to 80 minutes at 228° F. (5-lbs. pressure). Bower, (1931) reported that the optimum process is 80 minutes at 221.5° F.

After the cans are removed from the retort they are scrubbed in hot water to remove any grease or other debris and then plunged immediately into cold water. It is essential to cool the product in the shortest possible time in order to prevent the deterioration in quality which would occur if the product were air-cooled. After the cans are removed from the cooling tanks, they are dried in air currents.

When the cans are sufficiently cool they are sent through an automatic lacquering machine, where they receive a light coating of colorless enamel as a protection against rust, after which they are labeled and packed in cases. A standard case consists of 48 "halves." The standard case of imported canned crab is 96 "halves" and weighs approximately 80 pounds.

BLUE CRAB

Although the blue crab accounts for 90 percent of the production of crab meat in the United States, it is marketed almost entirely as fresh meat. A method was developed for canning this crab as far back as 1878, but the pack has never amounted to more than 2,000 or 3,000 cases, and in some seasons has not been prepared at all. The most important obstacles are:

1. Size. The blue crab is much smaller than either the Dungeness or king crab, and the cost per pound of picking the meat is greater.

2. Markets. The fisheries for this crab are within easy reach of the principal centers of consumption. Under normal conditions

a more satisfactory price has usually been obtainable for the fresh crab meat.

3. Discoloration. The meat of the blue crab is more subject to discoloration than other varieties, and in contrast discoloration is not limited to the surface and in most cases is apparently not caused by metallic sulfides. Discoloration is the principal obstacle to the development of an Atlantic crab canning industry.

Fellers (1936) has developed a method overcoming discoloration in blue crab meat, and a commercial pack of canned blue crab, using this method was placed on the market in 1938. This method may be used only on payment of license fees to the patent holder. The essential factors of his method are:

1. Precooking the crabs at a minimum time and temperature.
2. Picking and packing the meat as soon as possible after precooking.
3. Treating the precooked meat with a dilute aqueous solution of aluminium sulfate (maximum of 0.04 percent added to meat).
4. The use of higher processing temperatures and shorter times.

LOBSTER

Lobsters are canned only occasionally and in small amounts within the United States today. The last large commercial pack in the United States was canned in 1907. United States lobster canners moved their canneries to British North American territory when depletion of the lobster supply and regulations governing the size of lobster which might legally be taken made commercial operation generally unprofitable here. The canned lobster consumed in the United States is packed almost entirely in the Canadian maritime provinces and the colony of Newfoundland. Small amounts are packed occasionally in the United States in glass containers, but the pack has no great commercial importance, selling exclusively to a specialized delicatessen trade. Lobster canning is practicable in British territory as regulations do not forbid the use of "shorts," that is, lobsters less than 9 inches, as is the case here. Raw material is also cheaper and more abundant.

The American lobster, found on the Atlantic Coast of North America from Cape Hatteras to the Labrador, belongs to the genus and species *Homarus americanus*. It looks like the freshwater crayfish but is much larger in size. It has large claws which are not common to the sea crayfish, "spiny lobster" or "rock lobster" (*Panulirus interruptus*). The latter is not a true lobster. The lobster is dark green in color when alive and may reach a record length of 24 inches and 34 pounds in weight. The greater part of the catch does not weigh much more than 2 pounds each.

Lobsters are caught by the use of small flat-bottomed and semicylindrical traps or "pots," averaging about 4 feet long, 2 feet wide and 18 inches deep, constructed of spruce or pine building lath nailed lengthwise to a framework of half hoops made of green hardwood. The ends are fitted with funnels of tarred cotton or manila netting, 1 inch mesh tapering to a 6 inch wire ring or wooden hoop at the inner end which extends about 12 inches into the pot. The trap is baited and the catch removed through a hinged door in the top of the trap. The trap is weighted with bricks, stones or other weights. Scrap fish or fish waste such as cod, haddock or halibut heads are used as bait, the variety depending on the kind of bait available. Menhaden, flounders, sculpins and skates are used quite commonly. Lightly-salted half-rotten herring is a favorite bait in some localities. Some fishermen claim that stale bait is most effective as lobsters are attracted by the odor.

Lobsters may be taken at any season, but are most abundant and considered in best condition in summer. At this time of year the traps are set close together at depths of 2 to 10 fathoms. In winter lobster pots are set farther apart at depths of 10 to 25 fathoms. A fisherman may haul his traps every day in summer or about 3 to 4 times a week in winter. He may take his catch directly to the dealer or buyer, or may hold it in a live box until a buyer calls. The live boxes of the fisherman are usually rectangular boxes made of lath or light planking on a heavier framework, with sufficient space between planks to allow a free circulation of water. If the lobsters are not to be canned immediately they are transferred to live cars at the cannery. Any delay between killing and canning increases the possibility of blackening in the canned product.

The lobster catch is graded for size by the fisherman when hauling his pots. Lobsters over 9 inches long are kept for sale as fresh lobster, and the greater portion is sent to the United States. Lobsters 9 inches in length and under are shipped to the lobster canneries. Large lobsters are also canned occasionally when prices are low and demand poor in the fresh lobster market. So far as known there is no difference in quality between the meat of large and small lobsters.

When the lobsters are to be canned they are dropped alive into a tank of boiling water containing from 3 to 5 percent salt. In a few of the smaller and more primitive canneries the water is heated by fires directly under the boiler. Other plants use boiling tanks fitted with closed coils along the bottom and the water is heated by steam. The lobsters are cooked from 15 to 30 minutes after the water again starts to boil, the amount of variation de-

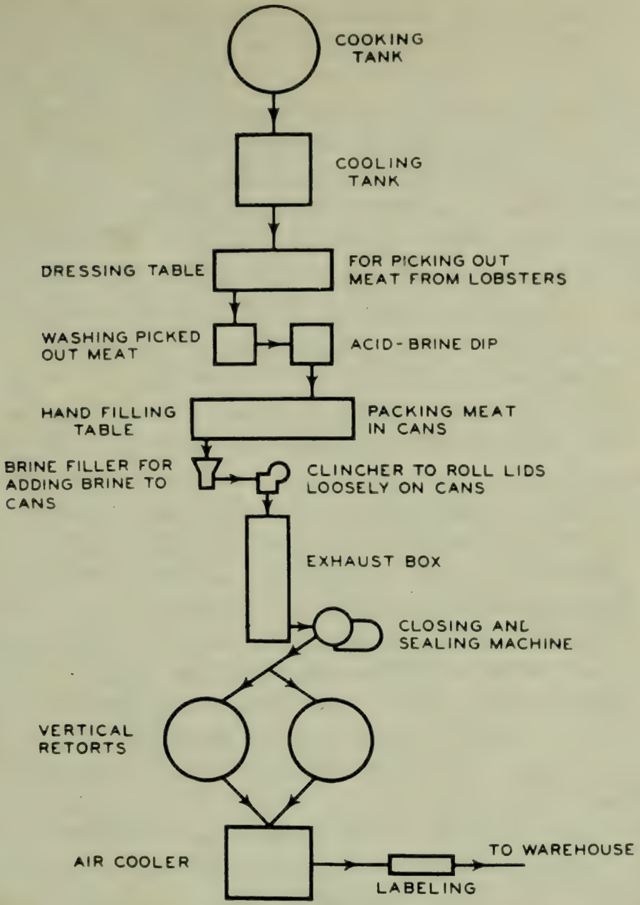

FIGURE 57.—Flow sheet for lobster canning.

pending on the quantity to be cooked at one time, and the size of the individual lobsters. The larger and more modern canneries cook the lobsters in lots of 500 pounds in live steam for 15 minutes at pressures from 5 to 10 pounds.

The cooked lobsters are cooled in a water spray or are lowered into tanks of water containing 5 to 6 percent salt. Cooling in sea water is not regarded as a good practice. Salt is added in cooking, both as a flavoring agent and to make the flesh somewhat firmer in texture. The lobsters are then piled on dressing tables where the tail and claws are pulled off, the body is split open, and the offal is removed. The meat is picked out by hand using a specially designed heavy knife. The tail is cut so that the meat may be removed in a few large pieces, the claws are cracked and the meat is pulled out with as little breakage as possible. The flesh from the legs is picked out in small pieces. The meat is sorted in picking and each grade is kept separate.

The picked meat is cleaned of clotted blood or other offal and is washed thoroughly but is not allowed to soak in running water. After draining it is dipped in brine containing a small amount of organic acid, usually citric, though acetic acid may be used. The added acid reduces or prevents darkening of the flesh through the formation of iron sulfide and lowers the pH. The amount used is so small that no acid flavor may be detected in the canned product.

Lobster is packed in quarter, half, three-quarter, No. 1 flat, No. 1 picnic and No. 1 tall cans having net weights of 3, 6, 9, 12, 7½ and 16 ounces respectively. The cans are "C"-enamel lined, seafood formula, with a second lining of vegetable parchment paper. Most of the pack is put up in quarter- and half-flat cans.

Cans are filled by hand, placing the tail meat on the bottom, the small pieces of leg meat in the center and claw meat on top, dark side up in "shingle fashion," alternating right and left claws to secure a good fill. To be suitable for canning, white meat must be free from discoloration and the red meat must have a clear bright color. Fancy grade canned lobster should contain only tail and claw meat. As the meat shrinks about 14 percent in processing, allowance must be made for this factor in filling the cans. Thus 7 ounces of meat are necessary to secure a cut out weight of 6 ounces. All filled cans are weighed to guard against under filling.

A small amount of 2- to 2½-percent salt solution is added to each can, that is, about ½ ounce for quarters, 1 ounce for halves, and 1½ ounces for ones. The brine must be freshly made and is boiled 30 minutes previous to use. It preserves the fresh lobster flavor in the canned product and aids in reducing darkening of the meat through over-processing.

Covers are clinched loosely on the filled cans which are exhausted for 9 to 12 minutes at 210 to 212° F. in hot water or steam exhaust boxes. The "exhausted" cans are sealed and processed. There is a great deal of variation in processing. The processes given here are used commercially but their accuracy has not been determined and the canner must judge their desirability on use. Quarter-pound (300 x 108 cans) with a 3-ounce fill are processed 40 minutes, half-pound cans (207 x 200) with a 6-ounce fill 45 minutes, and one-pound (404 x 206) cans with a 12-ounce fill 75 minutes, at 240° F. (10-lb. pressure).

The cans are water-cooled immediately after processing in a heavy water spray, or by immersion in cooling tanks. They are then cleaned, inspected for defective containers and stacked for labeling.

The cans may be labeled either by hand or machine after which they are packed in wooden cases of 96 halves or 48 ones for the European export trade. Lobster shipped to the United States is usually packed in fiberboard cases containing 1 or 2 dozen cans. Storage at temperatures about 40 to 50° F. is considered preferable if the pack must be held any length of time before sale and shipment. It is estimated that an average of 200 pounds of live lobster is required for a case of 96 halves. Breast, knuckle meat and liver are made into lobster paste. The lobster bodies are ground, packed in cans and sold as animal food.

SHRIMP

Shrimp packing is the most important seafood canning industry of the Gulf of Mexico and South Atlantic areas of the United States. It is estimated that the common shrimp, *Penaeus setiferus*, furnishes about 95 percent of the commercial catch, and the grooved shrimp, *P. brasiliensis,* 2.5 percent (Weymouth, Lindner and Anderson, 1933). These are the only species utilized in canning. The shrimp has a very short life history. According to Johnson and Lindner (1934), they probably survive barely a year. These references contain detailed accounts of the life history of the common shrimp together with much information on methods in this fishery.

The shrimp canning industry has placed itself under a voluntary inspection system administered by the Seafood Inspection Service of the U. S. Food and Drug Administration. To obtain this service the individual packer desiring inspection must apply for it. In order for his request to be granted, his equipment must comply with certain standards and the operation of the plant must conform to certain regulations drawn up by the Administration. The pack may not be shipped until passed by the inspector as satisfactory. Approximately 90 percent of the total pack is prepared under this inspection system, which has done much to improve the quality of the product and has resulted in the introduction of improved methods.

FISHING AREA AND EXTENT OF INDUSTRY

Shrimp are packed at 50 canneries located in Texas, Louisiana, Mississippi, Alabama, Florida, and Georgia. In Texas shrimp are canned at Corpus Christi, Aransas Pass and Palacios. Louisiana is the most important State in the shrimp canning industry and accounts for approximately half the catch. The industry is centered around New Orleans and Houma. The majority of the Mississippi shrimp canneries are in Biloxi and in Alabama shrimp are packed only at Bayou la Batre. In Florida shrimp are canned at a single locality on the Gulf Coast, Appalachicola, and only at Fernandina and St. Augustine on the Atlantic Coast. The Brunswick and Savannah districts are the shrimp canning areas of Georgia. Canning has been found unprofitable and has been abandoned on the northern coast of Georgia and in North and South Carolina.

The canning season opens about August 15, with the heaviest production usually in September and October on both the Atlantic and Gulf Coasts. Production declines gradually until after the first of the year when it reaches a minimum. The Gulf of Mexico also has a spring canning season running from about April 15 to June 10 with the peak of the season usually in May.

FISHING METHODS

The otter trawl is the chief type of gear used in catching shrimp for canning. This net, known as the shrimp trawl in the shrimp fishery, consists of a long bag in which the shrimp are caught and held; wings or walls of netting at each side of the bag, used in guiding shrimp into the bag; an "otter board" at the outer end of each wing, with the function of keeping the wings stretched apart and the mouth of the net open, while they also force the net to the bottom; and two tow lines, manila ropes ⅝ inch in diameter, attached to the otter boards and made fast aboard the fishing boat.

The nets vary from 20 to approximately 100 feet wide at the mouth. As a rule the smaller sized nets are used in the Gulf of Mexico. Molded leads are fastened to the "foot rope" or lead line at the bottom of the net, spaced from 4 to 20 inches apart, the intervals between leads shortening towards the otter boards. Corks or floats 3 to 4 inches in diameter are spaced from 2 to 8 feet along the top or "cork line." Shrimp trawls are made of cotton webbing, with a mesh of from 1½ to 2 inches, stretch measure. The mesh of the bag, or "cod end" is usually smaller and of heavier twine.

Unlike other otter trawls, two tow lines are used, one to each otter board. In the Gulf area these lines run to a winch in the bow, through snatch blocks mounted on each side of the wheelhouse at front and rear. The winch has usually been operated by hand, though power winches are now coming into wide use.

When the fishing boat is over a likely spot, the end of the trawl is thrown over and the net is allowed to run out over the stern as the boat goes ahead at slow speed. When the net is on the bottom, the otter boards act like kites, spreading out at an angle of 45° to the course of the boat, holding the mouth of the net open. The boat then goes ahead at a speed of about 2 to 4 miles an hour, dragging the trawl along the bottom. Any shrimp between the wings are thus forced into the bag. The length of time spent in dragging depends on the judgment of the fisherman, and may vary from 30 minutes to 2 hours. The depth of water in which the trawl is fished now varies between 5 to 90 feet, as productive areas at greater depths than were formerly fished have been discovered through the shrimp investigations of the Fish and Wildlife Service.

When the drag is completed, the boat is stopped with stern to windward so it will not drift down on the net, and the trawl is hauled in for removal of the catch. When the trawl is brought alongside, the "cod end" or bag is fastened to the sides of a collapsible rectangular wooden frame extending out from the side of the boat. The shrimp are removed by dip nets, which are "roused" or agitated in the water before lifting, to wash the shrimp. About 50 percent of the shrimp are already dead when they are taken out of the net and the rest die almost immediately. Fish, crabs, sticks, seaweed, and other debris are caught as well as shrimp, so the catch must be sorted and the trash discarded after it is brought on deck. The scrap fish may amount to as much as 50 percent of the catch.

TRANSPORTING THE CATCH

In the Mississippi and Louisiana areas, the canneries are located up bayous or at other points from 20 to 100 miles from the fishing grounds. Therefore, a transporter or "ice boat" must be near the grounds at all times, not only to receive the catch from the shrimp trawlers, but also to supply the fishermen with food and other necessities. A transporting boat usually anchors at some central spot to which the trawler brings its catch.

All transporters are shallow draft, with a maximum hold depth of not more than 5 feet. The hold is usually divided into compartments by removable board partitions, but is not insulated as experience has shown that the ice should melt at a fairly rapid and constant rate if the shrimp are to reach shore in good condition. The hold has a capacity of from 50 to about 200 barrels. A standard barrel of whole shrimp weighs 210 pounds. The hold is loaded in alternate layers of finely crushed ice and shrimp each about 6 inches thick. If the weather is warm, the layers of shrimp may be only 3 inches thick and the catch must be re-iced at the end of 12 hours if the boat has not reached the cannery.

Canning technologists believe that two improvements might be made in handling and transporting shrimp in order to further improve the quality of the canned product. First, the freight boats should follow the fishing fleet more closely, transferring the catch on the fishing grounds. This would reduce the variation in condition of raw material within a single load. Secondly, the heads should be removed as soon as the shrimp are caught, icing down only the edible tail portions. When shrimp are headed within 30 minutes after catching, the objectionable "black streak" or intestinal vein is removed with the head. Absence of the black streak would probably do more than anything else in the opinion of the housewife to improve the quality of canned shrimp. Elimination of the head and viscera would also reduce the rate of spoilage in the raw material. Shrimp boats of the South Atlantic Coast head shrimp when they are caught but only when the catch is light or the shrimp are large.

At shrimp canneries operating under the voluntary inspection system of the United States Food and Drug Administration, the ice boats cannot unload until the inspector determines the general condition of the raw material. If he gives permission the shrimp are unloaded. If he decides the shrimp are unfit for canning, the load must be destroyed or taken to a reduction plant.

Several methods of unloading are in use. In the area including Texas, Louisiana and Mississippi, a man in the hold scoops the shrimp into a galvanized wash tub with a blunt edged shovel. He lifts the filled tub by hand and passes it to a man standing on the deck who in turn transfers it by hand to a man standing at

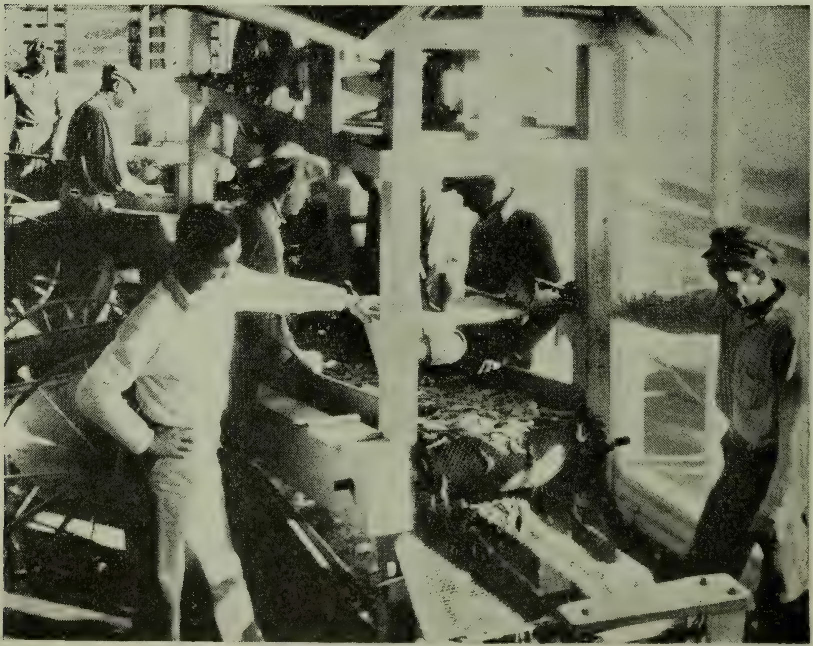

FIGURE 58.—Unloading, washing and inspection of shrimp. (Courtesy, Southern Shellfish Company.)

the head of the washing tank and inspection belt. Another common method is to swing a boom over the hold and hoist the tub of shrimp by block-and-tackle above the level of the wharf emptying it onto the end of the washer.

Some of the larger plants are introducing belt elevators of the general type used in other food canneries. The boot of the elevator is lowered into the hold, a man shovels the shrimp directly into the elevator and they are carried up to the washer by a belt with baffles spaced at regular intervals.

WASHING AND INSPECTION

There are many minor differences in the mechanical set-up of the apparatus used for washing and inspection of the shrimp upon unloading at the cannery. Generally, they are unloaded into a metal water tank with a baffle plate fixed several feet from the end extending above and below the surface of the water. The shrimp sink and are carried under the baffle plate and out of the tank on a conveyor belt. The ice in which the shrimp may have been packed is held back by the plate. The shrimp then fall into a revolving drum or "squirrel cage," where they are tumbled about, removing surplus water and any bits of debris such as seaweed, which is important, as shrimp are bought by weight. In Alabama, Mississippi and Louisiana some canneries use wire-mesh belt conveyors or vibrating screens for this purpose.

From the drum the shrimp are carried to the sorting conveyor which is usually an endless belt of wire mesh about 3 feet wide, 8 feet long and on a framework approximately 3 feet high. The shrimp are sorted as they pass over this belt by employees who work under the supervision of a government inspector. (Fig. 58.) Shrimp that are broken, torn, soft, discolored or otherwise defective are removed. This is an inspection for freshness and condition of raw material only. Other grading factors are not considered.

The shrimp fall from the end of a conveyor into a basket or metal lug box standing on platform scales. When the scales show a reading of 100 pounds net, the weight is checked, then noted down on tally sheets by a plant employee and the government inspector. Payment for the "green" shrimp is usually based on the figures shown on the tally sheets.

In Texas and on the Atlantic Coast, after washing and inspection the shrimp are iced down in refrigerator boxes or on the picking tables. This is done because the shrimp are landed at the cannery within an hour or two after catching and must be kept in ice several hours or they are not easily peeled. Shrimp landed at canneries in other areas have usually been held in ice long enough so that the shell is removed readily.

PICKING

As a rule, the baskets or lug boxes of shrimp are taken directly from the inspection belt to the picking room, where they are "picked" or "peeled." Shrimp are peeled entirely by hand, requiring a great deal of labor, as a satisfactory machine for this purpose has not yet been developed.

In picking, the body portion of the shrimp is grasped with the left hand, with the legs pointing outward and the head extending beyond the thumb. With the right hand the picker seizes the head and breaks it off, then inserts the thumb of the right hand between the rows of legs, breaking open the shell and peeling off a section about 1 to 1½ inches long. A pressure of the left hand on the tail of the shrimp forces the meat from the remainder of the shell. If the workmanship of the individual pickers is not inspected, the tails are apt to be torn off in order to increase the rapidity of picking. Thus, the last segment of meat is lost, increasing the loss in weight and also lowering the quality. It is believed the amount of clear, red color in canned shrimp is associated with the presence of this tail segment and decrease in amount of color makes the pack less desirable from a grade standpoint.

The picking room is entirely separated from the rest of the cannery, and the picking operation, like other steps in shrimp canning, shows evidence of improvement in handling. No two plants have exactly the same equipment and layout, but generally the whole shrimp are emptied from the baskets or lug boxes onto long metal or metal covered tables. These are about 25 feet long by 4 feet wide, usually sloping slightly from the sides toward the center, with each side divided into numbered spaces. A worker is assigned to each space and is given a corresponding number for identification. A metal flume is suspended above the middle of the table in some canneries or the table may be constructed with built-in flumes, running down each side.

The shrimp meat is dropped into the flume by the pickers as soon as the hull is removed. The hulls are dropped into a numbered bucket by the side of each worker. The piecework payment wage depends on the number of buckets of hulls picked by the worker. This method eliminates the delay which has always occurred previously in shrimp canning, through holding the meats in "cups" while picking. It also helps in washing the meats and is considered so highly that it was made mandatory in 1938 for all shrimp canneries under Federal inspection.[20] Only those canneries not under inspection now pick the meat into cups.

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[20] U. S. Food and Drug Administration. Revised regulations for inspection of canned shrimp effective July 1, 1938. 12 pp. Food and Drug Administration, U. S. Dept. of Agriculture. Washington.

A cup of alum water stands by each picker, into which the hands must be dipped at frequent intervals as the shrimp heads contain digestive juices which have a corrosive effect on the skin, unless this solution is used. A picker will peel from 100 to 400 pounds of shrimp in a day, depending on the size of the shrimp and the skill of the individual. The loss of weight in picking averages from 50 to 55 percent.

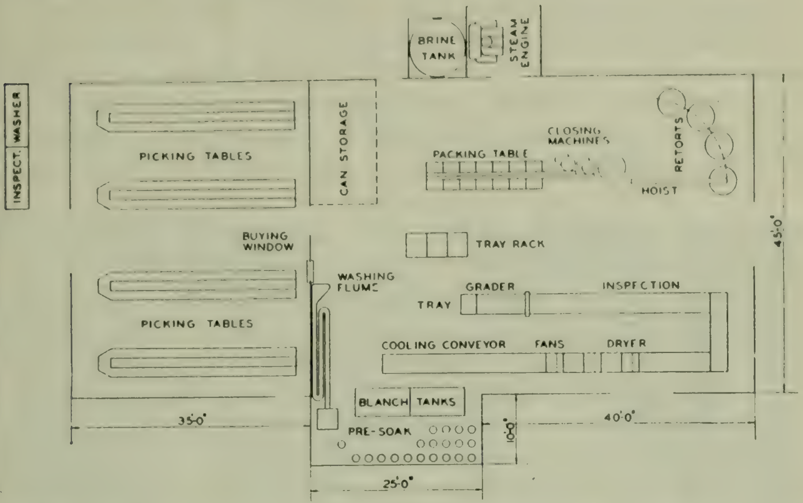

FIGURE 59.—Floor plan of a typical shrimp cannery. (Courtesy, American Can Company.)

PREPARATION FOR THE CAN

WASHING

After the shrimp have been peeled and the meats inspected, they are emptied into a washer. This is of the flume type and is usually constructed with built-in riffles or turns, whereby the meats are shaken about more vigorously and the effectiveness of the wash in increased. This flume also acts as a conveyor. At the end of the washer is a perforated metal plate or table where the wash water is drained away and the meats are again inspected.

BLANCHING

The "brining" or "pre-soaking" step has recently been abandoned by many packers. In theory it made the meats firmer in texture and was supposed to improve the color. This purpose is now accomplished by increasing the "blanch" or "pre-cook."

The washed and drained meats are emptied into metal baskets with a capacity of about 25 pounds. These baskets are lowered into a tank of boiling 50° salinometer brine. If the shrimp are to be canned "wet pack" they are blanched from 8 to 10 minutes, varying with size, or if preparing "dry pack" shrimp, 10 to 12 minutes. At the end of the blanching period, the baskets are raised by block-and-tackle and automatically dumped on a belt conveyor-drier.

One packer uses a continuous blanch which consists essentially of a tank of boiling brine, through which a conveyor passes. Wire baskets of shrimp are sent through the tank on this conveyor. The special features of this patented apparatus are the equipment for insuring uniform blanching.

Wooden blanching tanks described in the literature are no longer used, nor is brine made by adding salt to water in the blanching tank. Wooden equipment is not permitted, and practically all packers now use salt dissolving apparatus, manufacturing brine in quantities and storing it in tanks until it is required. The brine used in blanching is now tested and brought to strength between each batch of shrimp. The tanks are emptied and filled with an entirely fresh brine after every seventh cook.

Blanching is very important in determining the quality of the canned product. If the strength of the solution drops below 30° salinometer, the brine in the canned product may congeal, or "jell." Insufficient washing is also a factor in the congealing of canned shrimp during winter storage. Insufficient time in blanching may also cause jelling. If the brine solution is used for too many cooks or if too many shrimp are put in a basket, the brine will become "ropy" and the shrimp will have a ragged appearance. If the brine is not kept boiling vigorously, the meats will link together. This means that they will not curl, and therefore cannot go through the mechanical grader. The trade demands a well-curled shrimp and poorly curled shrimp are regarded as inferior. The loss in blanching or precooking is 45 percent of the picked weight.

DRYING

Some of the driers are simply moving wire-screen belts, above which are fixed large fans of the paddle wheel type. Others are enclosed by removable metal hoods and the fans are of the blower type. The shrimp which move over the conveyor at the rate of about 11 feet per minute are cooled and dried by currents of air from these fans. Approximately 3 minutes are required to dry the surface moisture from the cooked shrimp. The fan drier also removes antennae or "whiskers" and bits of shell. Drying is constant and not varied according to atmospheric conditions as was formerly the case. Therefore, portable screen trays on which cooked shrimp were dried in the open are no longer used.

INSPECTION AND GRADING

From the end of the drier the shrimp empty onto an inspection belt where they are scanned by several women who remove meats which are broken or otherwise unfit for canning (Fig. 60). From the inspection belt the shrimp pass to the grader, which consists essentially of an inclined aluminum plate in which numerous holes are bored. It is divided into three sections. In the first the holes are ⅝ inch, in the second they are about 1 inch, while in the lowest they may be 1½ inches in diameter.

When in operation, the grader moves from side to side with a vibrating motion. The small shrimp fall through the holes at the top of the plate. The larger meats pass over the small holes, but fall through the larger holes near the bottom. The biggest shrimp or "jumbos" fall over the end into a basket. Underneath each section of the plate is a metal chute with a double tray. The shrimp fall through the holes, down the chute and into the trays. The

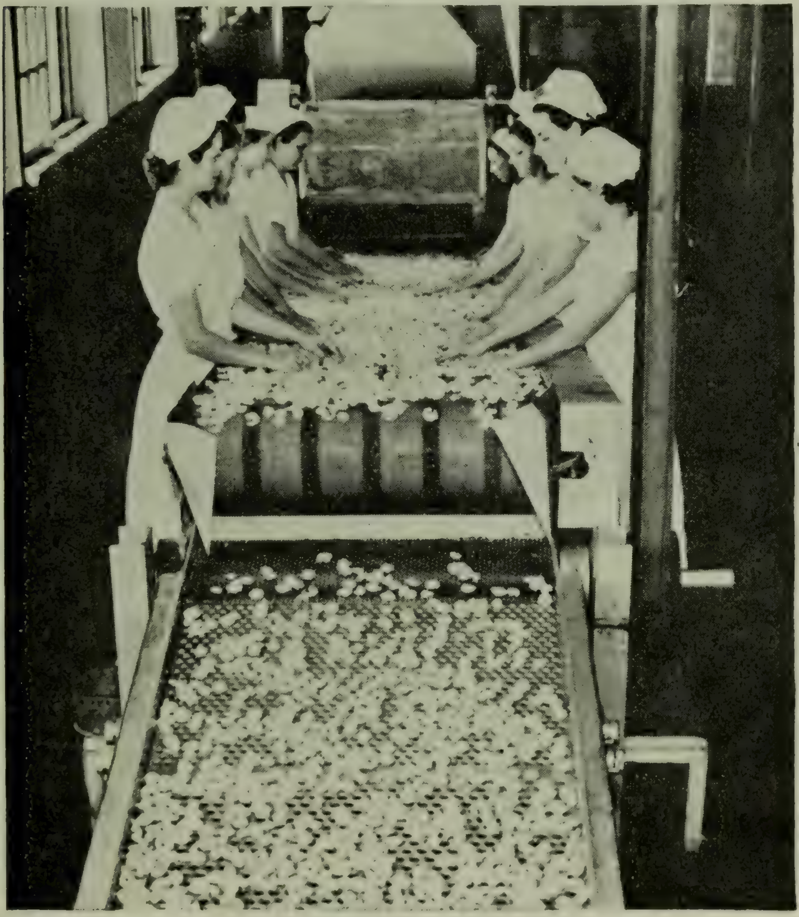

FIGURE 60.—Inspecting the cooked shrimp meats. Mechanical dryer in the ackground and a grader in the foreground. (Courtesy Southern Shellfish Company.)

filled trays are stacked in a rack nearby until sufficient shrimp of a size have been accumulated to justify packing that particular size or grade.

The "count" or number of shrimp filled into the can is the most important factor in grading. If the shrimp are to be packed as "extra large" or "jumbo," the count to a standard No. 1 can should be 20 or less, "large" may run from 20 to 25, "medium" from 25 to 40, and "small" over 40. "Pieces" must be so graded or as "broken" shrimp.

FILLING

The trays of shrimp are taken to metal surfaced packing tables with slotted spaces, just wide enough to hold a tray of shrimp. As a rule two girls work at each tray, one filling the cans while the other adjusts them to the correct weight (Fig. 61). No. 1 picnic (211 x 400) cans are used for the largest part of the pack. If "wet pack" shrimp are canned the drained weight must be 5¾ ounces for this size container, which requires a fill of 5⅜ ounces of shrimp meat as there is a slight increase in weight during processing, due to absorption of brine.

"Dry pack" shrimp in No. 1 cans are required to have a net weight of 5 ounces and are given a fill-in weight of 5⅛ ounces as there is a slight shrinkage in this method of processing. Cans for dry pack shrimp are usually lined with a one, two or three piece vegetable parchment paper liner. A three piece liner may be placed in the can more readily than a one piece liner. All cans are inside lined with "C"-enamel, seafood formula. Other sizes of cans used commonly, together with the fill-in weights are: Squat (307 x 208), wet pack 5⅜ ounces and dry pack 5⅛ ounces, and No. 1½ (307 x 400), wet pack 9¼ ounces, dry pack 9 oz.

The filling is watched by an inspector who removes occasional cans from the conveyor belt, checks the weights, empties out the contents, counts the number of shrimp to check the grade and watches for evidence of poor workmanship such as broken meats and bits of shell. In packing wet pack shrimp two methods are used in filling the cans with brine. In some establishments sprays of hot 2-percent brine fill the cans as they pass along a conveyor belt to the closing machine. In other canneries a 50- to 75-grain salt tablet, the size varying with the container, is dropped into each can, which is then filled with hot water as it passes along the belt. The tablets may be added either by hand or from a mechanical dispenser.

EXHAUST AND SEALING

Wet-pack shrimp are sealed immediately by a closing machine operating at a speed of 60 cans per minute. As the cans are filled

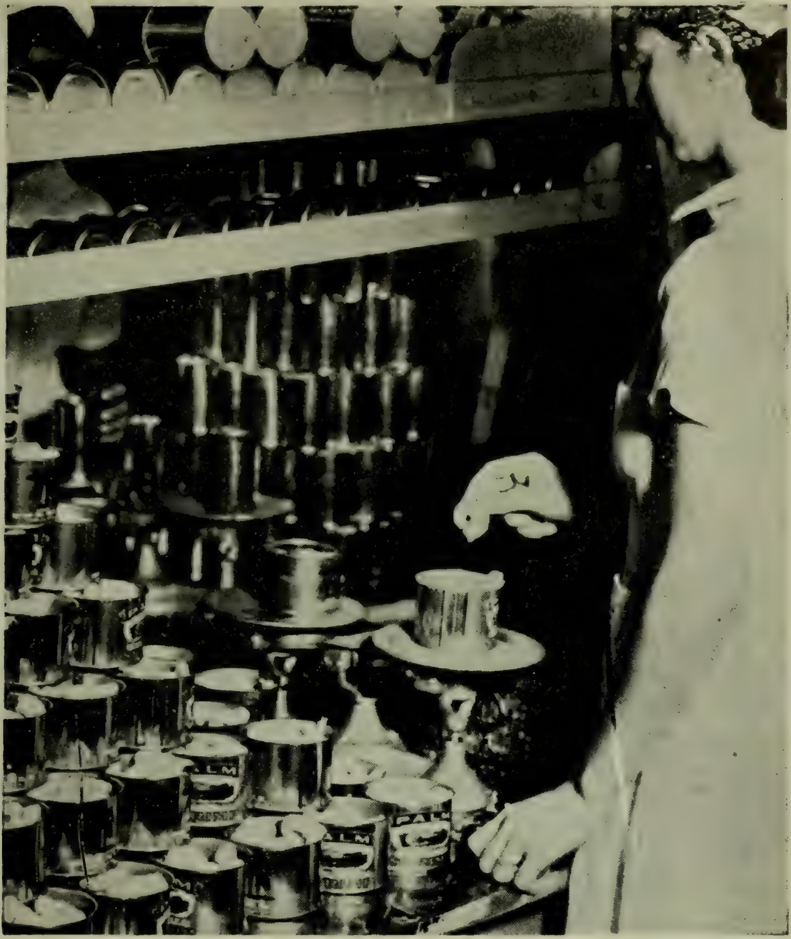

FIGURE 61.—Filling the containers with shrimp and checking the fill-in weight. (Courtesy, Southern Shellfish Company.)

with hot brine, creation of a vacuum mechanically or by heat exhaust is regarded as unnecessary.

Dry-pack shrimp may be given a mechanical vacuum seal or the cans may be sealed cold, without heat exhaust or mechanical vacuum. Vacuum packed shrimp are regarded as of superior quality, with a better color and flavor than non-vacuum packs, and constitute about 75 percent of the production of dry pack shrimp. Regulations of the U. S. Food and Drug Administration require a vacuum of not less than 12 inches in the can after processing, if it is to be labeled vacuum pack. The same process is given as for a non-vacuum pack. The process is shorter only if the cans are sealed with a vacuum in excess of 25 inches.

PROCESSING OR RETORTING

The sealed cans are stacked in retort baskets which hold about 640 No. 1 cans. A retort has a capacity of either 2 or 3 baskets. "Retorting" or "cooking" is controlled closely under the inspection regulations which also specify process times and temperatures. Wet-pack shrimp in No. 1 or squat cans are processed 20 minutes at 240° F. (10-lb. pressure) or 10 minutes at 250° F. (15-lb. pressure). No. 1½ cans are processed for 23 minutes at 240° F. or 12 minutes at 250° F. Dry-pack shrimp in No. 1 or squat cans are processed 85 minutes at 240° F. or 60 minutes at 250° F. if the can is lined with a one-piece parchment liner. If there is no liner or if a three-piece liner is used, the process is 70 minutes at 240° F. or 53 minutes at 250° F. While processing at 240° F. is permitted, the use of a 250° F. process is recommended as the better canning practice.

COOLING AND WASHING

At the end of the processing period the cans are water-cooled to a temperature of 98° F. before they are stacked in the warehouse. Canned shrimp may be cooled in special tanks or in the retorts. In the more up to date canneries or in the great majority of cases, the pack is cooled in the retorts. In canning wet-pack shrimp cooling in the retorts aids in preventing overcooking and softening, while in dry-pack shrimp it aids mechanically in pushing the can ends back in place, that is, where a non-vacuum seal is used. Alkaline solutions are not required in cleaning shrimp cans after processing.

STORAGE, LABELING AND SHIPPING

Shrimp usually are held about 48 hours before labeling and casing. Conditions of labeling, storage and shipping are specified in the inspection regulations. All inspected cans are now coded so that any lot may be identified. No lot or code may be labeled until it has been examined and passed by the inspector. In addition the thermometer chart must be checked to determine sufficiency of cook and each cook must be identified with the corresponding code mark and date. The packer is required to keep these records at least one year. A standard case of canned shrimp contains 48 No. 1 picnic cans.

Any labels used for inspected canned shrimp must be approved by the U. S. Food and Drug Administration; this ruling applies to canned shrimp only and not to other canned products. Such labels may bear the statement "Production supervised by U. S. Food and Drug Administration," which may not appear on uninspected canned shrimp or on shrimp intended for export. Both labeling machines and hand labeling are used in labeling the cans. Each lot or "code mark" is stored and must be held separate. No lot may be shipped until the inspector issues a certificate to the packer, stating that the parcel complies with all regulations.

SHRIMP PACKED IN GLASS

An increasing amount of shrimp is being packed in glass. Only the best color grades in the larger sizes are packed in glass, since appearance is the principal sales appeal factor. The method of handling the shrimp is identical with packing in tin up to and including filling.

Several sizes of glass containers are used, but the most common are the 8-ounce tumblers, with a drained weight of 5¼ ounces and a fill-in weight of 5 ounces; and the 9-ounce tumbler which holds 6¾ ounces drained weight and 6⅛ ounces fill-in weight. If the containers are overfilled "jelling" occurs, while "slack fill" shrimp soon present a ragged, unattractive appearance. Other containers used are a tumbler holding 2½ ounces, packed principally for the English market, and a "nappy" jar for "cocktail" shrimp filled in rosette style. The containers are filled with a 3-percent brine, filled hot at temperatures varying from 160 to 180° F. The jars are sealed in a glass pack vacuum closing machine, under a vacuum of not more than 20 inches. Higher vacuums cause ebullition with loss of brine.

The sealed containers are placed in retort baskets with a rubber mat between each layer. Mats protect the enamel lids against damage during processing, such as fading, scratching or blistering. The process times specified for glass containers under inspection regulations are: 5 to 9 ounces inclusive, 22 minutes at 240° F. (10-lb. pressure) or 14 minutes at 250° F. (15-lb. pressure).

The pack is cooled in the retort under pressure so that lids will not be blown off the jars. The cooling water is admitted at a temperature of 190° F. until the retort is one fourth full; then at 170° F. until the half-way mark is reached; at 140° F. until it is three-fourths full, when the temperature is dropped to 100° F. When the retort is full, water runs through at normal temperature or at from 60 to 70° F., for about 10 minutes. The entire cooling process requires about 35 minutes (Anchor Cap and Closure Corp., 1926).

After cooling, the containers are dried, labeled by hand and packed in corrugated fiberboard cartons, 2 dozen jars to a carton. Glass-pack shrimp are very attractive as a display product, but the retailer should be warned that the glasses must not be left long in a strong light, as the shrimp may then become "lightstruck."

SPECIALTY PRODUCTS

Specialty products may be defined as articles in which fish is only a portion of the ingredients, or which require a greater amount of preparation for canning than is usual. Soups, chowders, stews, and various kinds of fish cakes are the principal commercial types, but any ready-to-serve dish containing fishery ingredients should be included. A variety of such products is canned from time to time, but only those specialties prepared regularly are included in this publication.

CLAM CHOWDER

Two types of clam chowder are canned, "Manhattan" "Rhode Island", or "Coney Island" chowder; and the "New England" variety. The method of packing New England clam chowder is generally the same in all plants, but the formula for Manhattan chowder differs with each packer.

Both soft clams and quahogs are used, the species usually depending on whichever is most abundant. Quahogs are preferred by some packers as the clam flavor is stronger. Potatoes used for chowder should be firm-textured, with few and shallow eyes, regular shape and smooth surface. Salt pork should be fresh and free from rancidity, usually a good grade of fat brisket pork. Smoked bacon is specified in some published formulae, but is not favored in practice. In packing Manhattan style chowder, standard grade tomatoes in "gallon" (No. 10) cans are generally used. Carrots, celery, peppers or any other vegetables are fresh and of the best market quality.

MANHATTAN STYLE CHOWDER

A commercial formula for Manhattan style chowder contains the following ingredients:

65 lb.	fine cracker crumbs	24 No. 10 cans	tomatoes
18 lb.	ground salt pork	16 lb.	salt
18 lb.	ground onions	5 oz.	white pepper
55 gal.	water		

In making this chowder, 18 pounds of diced onions are simmered in the bottom of an 80-gallon steam-jacketed kettle. When they are soft, 18 pounds of ground salt pork are added. The pork and onions are then sauted until they are soft, but not brown, when 15 gallons of water are poured in and allowed to come to a boil. During this time 35 pounds of fine cracker crumbs are placed in a mixer with 15 gallons of water and beaten until smooth and the mixture is added to the boiling contents of the kettle.

A second batch of 30 pounds of fine cracker crumbs is placed in the mixer with 10 gallons of water and beaten until it is smooth. An additional 15 gallons of water is poured into the kettle when the contents have reached a temperature of 200° to 212° F., and when this boils the second batch of cracker-water mixture is added.

When the broth has been brought to the boiling point for the fourth time, the contents of 24 No. 10 cans of tomatoes are added, together with 16 pounds of salt and 5 ounces of white pepper. The soup is drawn off to the reservoir tank of a syrup filling machine such as is used in fruit canneries. Clam juice may be substituted for a portion of the water, but as a rule the liquid in Manhattan style chowder is water.

Meanwhile the potatoes have been mechanically peeled and de-eyed by hand. They are diced into 3/8 inch cubes and finally are blanched for 1 or 2 minutes or placed in sufficient water to cover to prevent discoloration. The clams are washed thoroughly to remove as much sand as possible. In some canneries they are then steamed sufficiently to open the shells, the siphon is removed and the whole clam is ground. Other canners use raw shucked clams removing the "stomach" or dark body mass and cutting off the siphons before grinding. This is believed to reduce the possibility of darkening.

Cans are usually lined with "C" enamel, seafood formula. Girls stationed on each side of a filling table place 2 ounces of potatoes in each No. 1 picnic can. Other girls then add 2 ounces of clam meat. If No. 3 cans are being packed the amount is 7½ ounces of potatoes and 7½ ounces of clams. The filling machine adds sufficient hot broth to fill the cans and they are sealed immediately. The process for No. 1 cans varies from 45 to 50 minutes and for No. 3 cans, 85 to 90 minutes at 240° F. (10 lb. pressure). The pack is water-cooled immediately after processing.

NEW ENGLAND CLAM CHOWDER

The method used for making New England style chowder follows the general outline just described, except that clam juice, previously heated to remove suspended solids, replaces at least a portion of the water, and no tomatoes are included, the only ingredients being potatoes, pork, onions, clams, juice, cereal "filler," and seasoning. Clams are added whole or only coarsely chopped. Flour is substituted for cracker crumbs. For the exact formula and method of preparing the soup, refer to the preparation of fish chowder. The processing times vary within the range previously given, but tend toward the upper limit. This pack is also water-cooled.

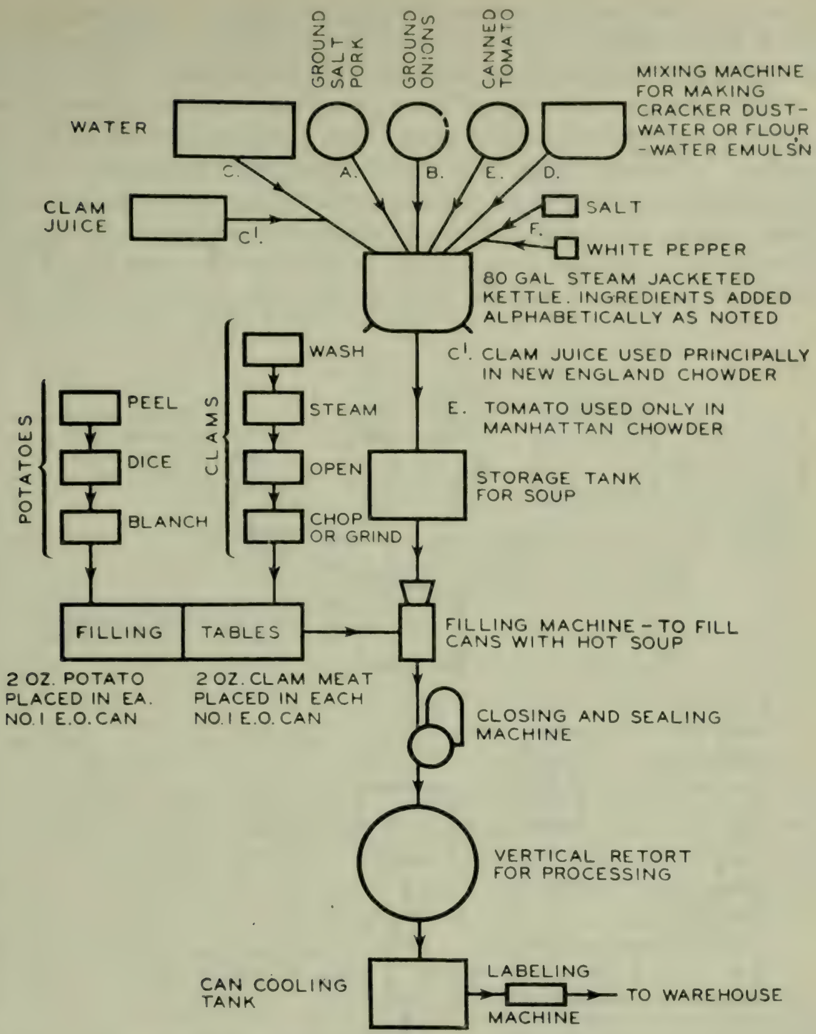
GROUND SALT PORK
GROUND ONIONS
CANNED TOMATO
MIXING MACHINE FOR MAKING CRACKER DUST-WATER OR FLOUR-WATER EMULS'N
WATER
C.
A.
B.
E.
D.
CLAM JUICE
C¹.
SALT
F.
WHITE PEPPER
80 GAL STEAM JACKETED KETTLE. INGREDIENTS ADDED ALPHABETICALLY AS NOTED
C¹. CLAM JUICE USED PRINCIPALLY IN NEW ENGLAND CHOWDER
E. TOMATO USED ONLY IN MANHATTAN CHOWDER
CLAMS
WASH
STEAM
OPEN
CHOP OR GRIND
POTATOES
PEEL
DICE
BLANCH
STORAGE TANK FOR SOUP
FILLING TABLES
FILLING MACHINE - TO FILL CANS WITH HOT SOUP
2 OZ. POTATO PLACED IN EA. NO. 1 E.O. CAN
2 OZ. CLAM MEAT PLACED IN EACH NO. 1 E.O. CAN
CLOSING AND SEALING MACHINE
VERTICAL RETORT FOR PROCESSING
CAN COOLING TANK
LABELING MACHINE
TO WAREHOUSE

FIGURE 62.—Flow sheet of clam chowder canning.

In some canneries, chowder is made by the batch process, with all ingredients pre-cooked together in 80 gallon steam-jacketed kettles and paddles are used to stir the ingredients. This method is somewhat cheaper but it is claimed that the mixing is not efficient enough to give an even blend of ingredients in the can.

FISH CHOWDER

"Fish" chowder or "haddock" chowder is an "off-season" product, prepared when potatoes and fish are cheapest. Skill and experience are required, since carelessness or ignorance may result in discoloration and off flavors.

The fish are usually trawler-caught haddock. The broth portion is generally made from cod heads or fish filleting trimmings, of a quality equal to those portions sold in the fresh fish trade. For fish chowder, a firm textured potato of high starch and low moisture content is required, smooth in shape with eyes few and shallow. Potatoes with low starch and high mosture content "mush up" in processing. Potatoes should be blanched to avoid discoloration. Green Mountain potatoes are preferred for use in fish chowder. Salt pork should be of good quality and free from rancidity. Onions should be large in size and moderate in flavor.

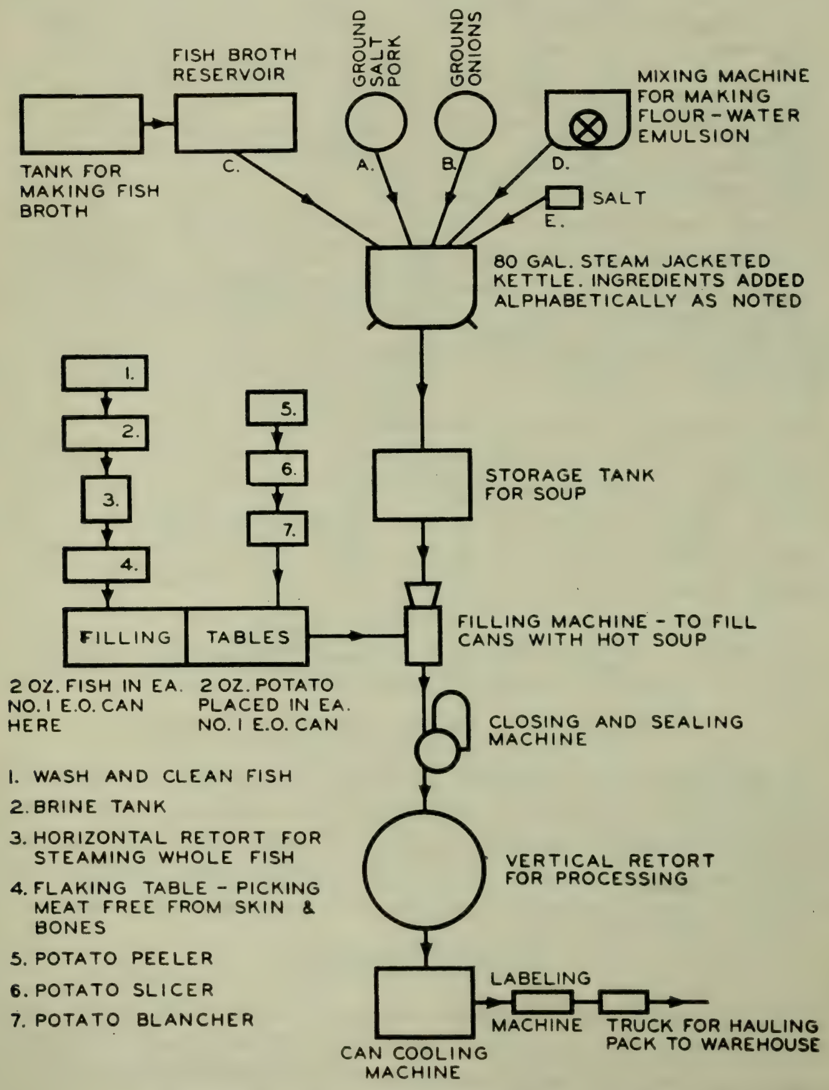
FISH BROTH RESERVOIR
GROUND SALT PORK
GROUND ONIONS
MIXING MACHINE FOR MAKING FLOUR-WATER EMULSION
TANK FOR MAKING FISH BROTH
C.
A.
B.
D.
SALT
E.
80 GAL. STEAM JACKETED KETTLE. INGREDIENTS ADDED ALPHABETICALLY AS NOTED
1.
2.
3.
4.
5.
6.
7.
STORAGE TANK FOR SOUP
FILLING
TABLES
FILLING MACHINE - TO FILL CANS WITH HOT SOUP
2 OZ. FISH IN EA. NO. 1 E.O. CAN HERE
2 OZ. POTATO PLACED IN EA. NO. 1 E.O. CAN
CLOSING AND SEALING MACHINE
1. WASH AND CLEAN FISH
2. BRINE TANK
3. HORIZONTAL RETORT FOR STEAMING WHOLE FISH
4. FLAKING TABLE - PICKING MEAT FREE FROM SKIN & BONES
5. POTATO PEELER
6. POTATO SLICER
7. POTATO BLANCHER
VERTICAL RETORT FOR PROCESSING
LABELING MACHINE
TRUCK FOR HAULING PACK TO WAREHOUSE
CAN COOLING MACHINE

FIGURE 63.—Flow sheet of fish chowder canning.

The first step in packing fish chowder is to make the broth. About 1,750 lb. of fillet trimmings or cod heads enclosed in cloth or cotton mesh bags are placed in a tank with 500 gallons of water. Sometimes the fish are placed directly in the water, straining out the solid material after the mixture has simmered for 2 hours. The broth is then drawn off to a reservoir tank. As this step requires much time, two tanks are used by most canners for making broth, one batch cooking while the other is being drawn off for use.

Fish chowder "soup" ingredients:

50 lb. flour
18 lb. diced onion
18 lb. diced salt pork
56 gal. fish broth
25 gal. water
16 lb. salt
5 oz. white pepper

While the broth is cooking, 18 pounds of diced onions are simmered until they are soft in an 80 gallon steam-jacketed kettle. Then 18 pounds of diced pork are added and while the pork is cooking, 25 pounds of flour is beaten in a mixing machine or "milk-beater" with 15 gallons of water until smooth and creamy. When the pork is soft, 20 gallons of broth are poured in the kettle and on reaching the boiling point, the flour emulsion is added. While the contents of the kettle are brought to a boil, a second batch of 25 pounds of flour and 10 gallons of water is prepared. Twenty gallons of broth are poured into the kettle when the mixture is again boiling, and when this in turn has boiled, the second batch of flour emulsion is added. Sufficient broth to bring the contents up to about 80 gallons, and 16 pounds of salt, are added when the mixture is boiling for the fourth time. When the broth boils for the fifth time it is drawn off to a tank connecting with the filling machine.

The empty cans move along a filling table on belt conveyors. Girls at the first section of the table add 2 ounces of haddock to each No. 1 picnic can from scoops which hold the exact quantity required. The fish may be steamed, as in pre-cooking fish flakes, but some packers use raw fish, cut in small chunks. At the second section of the table, 2 ounces of diced raw or blanched potatoes are added. Raw potato is reported to give the product a faintly unpleasant flavor.

Some packers add from 0.8 to 0.9 gram of citric acid to each can at this time. This harmless organic acid is used as a preventive against discoloration. The cans then pass to the filling machine which is a syrup filler of the type used in fruit or vegetable canning, where they are filled with a measured volume of broth. The cans are sealed without exhaust as the temperature of the contents should be about 165° F.

The process for fish chowder in No. 1 picnic cans varies from 60 to 75 minutes at 240° F. (10-lb. pressure). The pack is water-cooled immediately after processing.

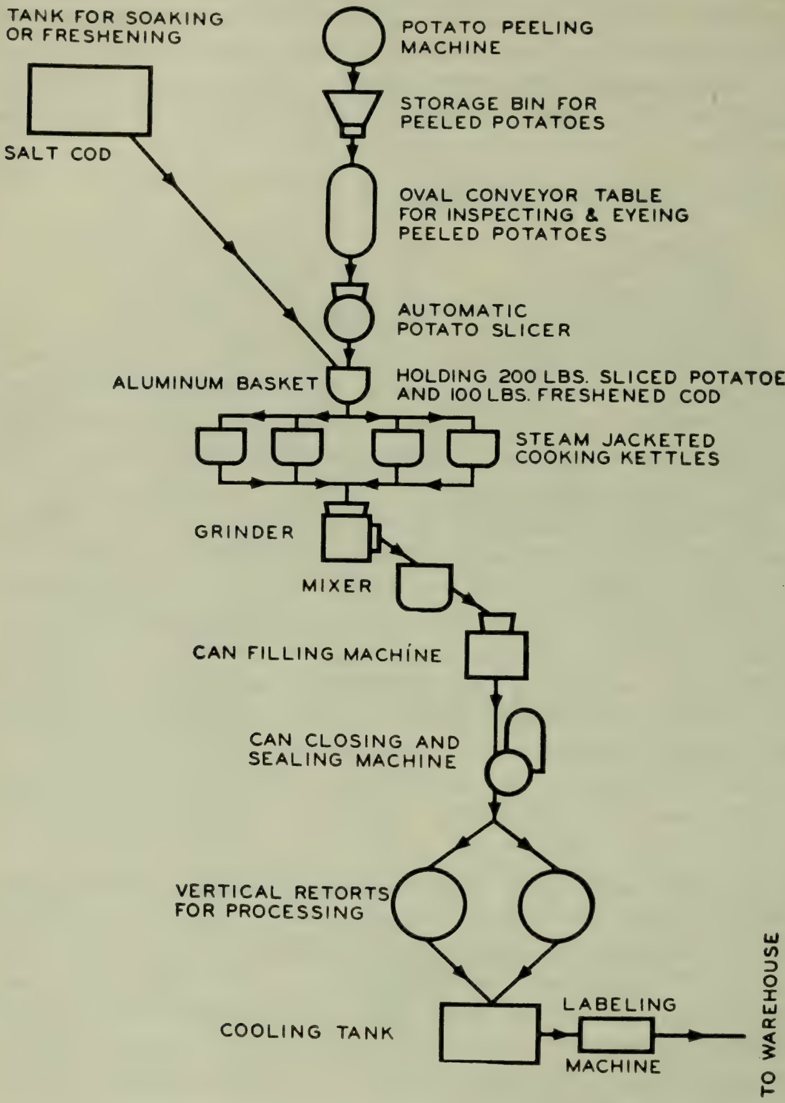
TANK FOR SOAKING OR FRESHENING
SALT COD
POTATO PEELING MACHINE
STORAGE BIN FOR PEELED POTATOES
OVAL CONVEYOR TABLE FOR INSPECTING & EYEING PEELED POTATOES
AUTOMATIC POTATO SLICER
ALUMINUM BASKET
HOLDING 200 LBS. SLICED POTATOES AND 100 LBS. FRESHENED COD
STEAM JACKETED COOKING KETTLES
GRINDER
MIXER
CAN FILLING MACHINE
CAN CLOSING AND SEALING MACHINE
VERTICAL RETORTS FOR PROCESSING
COOLING TANK
LABELING MACHINE
TO WAREHOUSE

FIGURE 64.—Flow sheet for the canning of fish cakes.

FISH CAKES

The best quality salt cod and Green Mountain potatoes are generally used by canners of fish cakes. The ingredients are:

200 lb. potatoes	5 lb. hydrogenated coconut oil
100 lb. shredded salt cod	2 oz. white pepper

The cod is soaked in water to freshen about 10 hours, or 1½ hours if running water is used. The potatoes are peeled by machine, afterward passing along a conveyor where they are inspected by women who remove any "eyes" or bits of skin not taken off in the machine. They are then weighed in lots of 200 pounds and automatically sliced, falling into a large aluminum basket with perforated sides and a trap-door bottom.

One hundred pounds of shredded, freshened cod are added to 200 pounds of potatoes in the basket and carried to a steam-jacketed kettle partly filled with boiling water. The contents of the basket are boiled for 30 minutes, and conveyed to a plate type power driven grinder.

The ground mass is emptied into a mixer, together with 5 pounds of hydrogenated coconut oil and 2 ounces of white pepper, and mixed thoroughly for 5 minutes. The mixture is gradually dropped into the hopper of a filling machine which delivers a measured volume of material to each can.

Since this is a hot pack, no exhaust is used. The cans are sealed immediately at the rate of 60 per minute. Most of the pack is put up in 8-ounce flat cans, though a small amount is canned in No. 10 containers. The process for 8-ounce cans is usually 75 minutes at 240° F. (10-lb. pressure). No. 10 cans are processed 240 minutes at the same temperature and pressure. The pack is water-cooled immediately after processing.

Some packers add a small amount of citric acid dissolved in water when the fish cakes are in the mixer in order to inhibit discoloration. The product will taste decidedly sour if an excess of acid is used. A number of published formulae include onions and some fat such as beef tallow. Such ingredients are not generally used in the commercial canning of fish cakes.

FISH BALLS (FISKEBOLLER), NORWEGIAN STYLE

While a portion of the domestic supply of Norwegian-style fish balls is imported from Norway, "Fiskeboller" are also packed by fish canners in the United States.

A typical formula used in the United States is:

56 lb. cooked ground haddock
5 gal. whole milk
5 gal. fish broth
2 lb. potato flour
1 lb. wheat flour
1 lb. salt
Nutmeg and ginger to taste

The haddock must be fresh, the milk sweet and fresh. Milk powder is often used in place of fresh milk as the quality is more easily controlled, and the product is more uniform. Nutmeg and ginger are generally used in the form of essential oils in an alcoholic solution.

The fresh whole haddock are washed, cleaned and placed in large shallow aluminum pans with perforated bottoms. The pans of fish are steamed for about 15 minutes at 240° F. (10-lb. pressure) or until the meat can be separated easily from the skin and bones. The flakes are ground through a three-eighths inch plate grinder.

The milk, fish broth, flour and seasonings are beaten to a creamy liquid in a mixing machine. The ground haddock is then added slowly and the mixture is beaten until it is a homogenous mass. The paste is filled into the hopper of an apparatus resembling a doughnut machine, which forms small cakes of the material, dropping them into a pan of hot water, where they remain about 10 minutes until "set."

The fish balls are then hand packed into "two-ration" (squat) and "four-ration" (1 lb.-flat) cans. The cans are filled with hot fish broth, made as described in the canning of fish chowder and are sealed at once without exhaust. The process for two-ration cans is 75 minutes, and for four-ration cans, 80 minutes at 230° F. (5-lb. pressure). The pack is water-cooled in tanks immediately after processing.

TURTLE AND TERRAPIN PRODUCTS

GREEN TURTLE SOUP

Green turtle soup is canned in New York and one or two other localities on the Atlantic seaboard, utilizing green turtles (*Chelonia mydes*) imported from Central America, especially from Yucatan, British Honduras, Nicaragua and the West Indies. Some of these turtles are taken by hand when they come up on land, but most are caught in tangle nets, a type of gill net. The nets and method of fishing have been described by Fiedler and Jarvis (1932).

> These nets are from two to three fathoms deep and from five to 50 fathoms long. They are made with a 20-inch stretched mesh. A cork line of manila rope is run along the upper selvage and a lead line of the same material run along the lower selvage of the net. The corks are 2-inch blocks of wood made from the wood of the boya tree, a light wood resembling that of the mangrove tree. Some corks are also made from slab cork purchased in St. Thomas. The corks are spaced at intervals of 12 inches. Leads are fastened along the ground line at intervals of about 16 inches.
>
> Turtle nets may be fished as drift nets or as sunken nets. The latter type is anchored by stone killicks lashed in a loop of the lead line at each end of the net. Buoy lines with marker buoys are fastened at each end of the cork line. Marker buoys are made from blocks of wood. A 50 fathom net is said to cost twenty dollars for material.
>
> The nets are set in locations known to be frequented by turtles, with a wooden decoy roughly shaped like a turtle attached to each net. Turtles, attracted by the decoy, are entangled in the mesh of the net.

The turtles which weigh from 100 to 300 pounds are held in tanks or pens and shipped alive to Fulton Market, New York. Several published formulae are available but are useful only as guides and must be modified as experience indicates. The formula given below is of that type:

20 lb. turtle meat
20 lb. beef bones
10 gal. water
2 lb. diced onions
2 qt. sherry
1½ pt. olive oil
1 lb. flour
¼ to ½ lb. salt
8 fl. oz. Worcestershire sauce
3 oz. minced parsley
2 oz. cayenne
1 oz. marjoram
1 oz. thyme
½ oz. bay leaves
½ lb. diced celery

Instead of water 10 gallons of stock made by boiling the head, liver, lungs, heart, flippers, and shell in water, may be substituted. If this is done, beef bones are not needed. Otherwise, the beef bones are boiled in the 10 gallons of water, together with the celery, marjoram, thyme, bay leaves and parsley. While the stock is cooking, the meat, diced into small cubes, is cooked slightly over a low fire for 15 to 20 minutes in ¾ pint of olive oil.

At the same time the diced onions are cooked in the other ¾ pint of olive oil until brown, then strained out. Then 1 lb. of flour is added slowly to the oil and cooked, stirring meanwhile, until a smooth brown roux is obtained.

The stock is filtered until clear, then the roux is added gradually, mixing so that the soup will not be lumpy. The cooked meat is added, together with the salt and cayenne pepper. When the soup approaches boiling temperature again, the Worcestershire sauce and sherry are added, the soup is stirred vigorously, filled into containers and sealed immediately while hot.

Turtle soup is packed in containers varying from No. 1 picnic (211 x 400) to No. 2½ (401 x 411) cans. Representative processes are, for No. 1 cans 45 minutes and for the No. 2½ containers 65 minutes at 240° F. (10-lb. pressure). The pack is water cooled in tanks immediately after processing.

Some published formulae include lemon juice and chopped hard boiled egg yolks. It is understood that better results are obtained when these ingredients are added to taste by the consumer. Cooking sherry may be used, but imported sherry is favored for a fancy product. Some chefs prefer turtle soup without sherry, adding it to taste when serving the soup.

SNAPPING TURTLE SOUP

Two species of snapping turtle are canned to some extent, the common snapping turtle (*Chelydra serpentina*) and the hardshell, or alligator turtle (*Macrochelys lacertina*). The common snapping turtle may reach a maximum weight of 40 pounds, but is usually much smaller. The common snapping turtle is taken commercially in the States around the Great Lakes, along the Mississippi River, and in New Jersey, Delaware, and Virginia. Snapping turtles are taken commercially by fyke nets, fish pots, haul seines, gaffs, hand lines, trot lines, and by hand, that is, simply picked up by the fishermen. Snapping turtles should be alive when marketed and Cobb (1919) stated that the females are best for canning.

"Snapper soup" is canned using the formula given for green turtle soup, or the following:

30 lb. snapper meat
10 gal. water
1 No. 10 can tomatoes
2 lb. minced onions
2 lb. lard
1 lb. flour
2 oz. minced garlic
2 oz. minced parsley
2 oz. white pepper
2 oz. whole cloves
½ oz. mace
½ oz. bay leaves
Salt to taste

The snapping turtles are beheaded and hung head downward until the blood ceases to drip. The turtles are cleaned, taking care not to break the gall bladder. The meat is separated from the bones and cut in small pieces. The meat is simmered, together with parsley, cloves, mace and bay leaves. The onions are fried in lard until brown, when they should be removed. The flour is added to the lard gradually, stirred slowly until an even blend is obtained and cooked until the roux is brown.

After about 15 minutes parboiling, the meat is removed to drain and the liquid is strained to obtain soup stock. The drained meat is fried lightly in ham fat or bacon drippings until the surface is a light brown. The roux is added to the stock gradually, followed by the tomatoes and meat. When the soup boils, the pepper and salt are added, the mixture is filled into No. 1 picnic (211 x 400) cans and sealed immediately while hot. The process is 40 to 45 minutes at 240° F. (10-lb. pressure) and the pack is usually water-cooled in tanks to about 100° F.

SNAPPING TURTLE STEW

"Snapper stew" is also canned in small quantities. No standard formula is used, but that given by Cobb (1919) is typical. A formula used in Louisiana for "Ragout de Tortue à la Bourgeoise" follows:

20 lb. snapper meat
1 lb. minced onion
½ lb. flour
½ lb. lard or
1 c. olive oil
⅛ oz. bay leaf
5 pt. water
½ pt. Madeira wine
⅛ oz. minced garlic
⅛ oz. thyme
Salt to taste

The meat is diced into cubes about 1-inch square. The onions are cooked with the lard or olive oil and garlic until yellow. Then flour is added slowly and the meat is put in. After the surface of the meat is braised slightly, water is added slowly. When the stew approaches the boiling point, Madeira wine and seasonings are added, the mixture is stirred well and filled into No. 1 picnic cans which are sealed immediately without heat exhaust or vacuum seal. The pack is processed for 45 to 50 minutes at 240° F. (10-lb. pressure), and is water cooled in tanks.

TERRAPIN STEW

The salt-water or "diamond-back" terrapin (*Malaclemmys palustris*) is the most highly prized of the edible turtles in the United States. At one time demand, together with depletion of the supply, made the wholesale price as high as $60 per dozen. It is found in salt marshes along the coast from New Jersey to Texas. While a few are obtained commercially from Delaware and southern New Jersey, the main supply comes from the South Atlantic and Gulf Coast States. The average weight is about 4 pounds, with a maximum slightly over 6 pounds.

Fresh-water terrapin are used as a substitute for the more highly valued "diamond-back," principally along the lower Mississippi. The species used most commonly for food are the "red-bellied terrapin" (*Pseudemys rugosa*), the "mobilianer" (*P. mobiliensis*) and the "yellow-bellied terrapin" (*P. scabra*).

The common method of taking diamond back terrapin is by "probing." The fishermen wade through the mud along the borders of salt lagoons or marshes, probing in the soft mud with a pointed stick. Fresh-water terrapin are often caught in fyke nets or taken by hand. Drag nets, haul seines, and dip nets are also used in catching terrapin.

Diamond-back terrapin is canned in Maryland and at one time small amounts were packed in Georgia. Some terrapin is still canned in Louisiana, utilizing the fresh-water species. Though packed commercially, canned terrapin is not an important product. The following formula for canning terrapin stew was given by Cobb (1919):

24 terrapin	6 doz. egg yolks, hard boiled
10 lb. butter	12 pt. sherry

When ready for canning the terrapin are washed and plunged alive into salted boiling water, and cooked until the toenails and outer skin come off readily. When they are removed, the terrapin then are placed in clear salted boiling water and cooked until the legs are quite tender. They should then be cleaned the same as snappers except that the small intestines are saved and cut into very small pieces.

The cut meat, together with the intestines, liver, eggs and liquor is then placed in a kettle together with 10 pounds of butter. This is brought just to a boil, and the egg yolks, which have been mashed and creamed with 12 pints of sherry wine, are added. The prepared product is filled in No. 1 cans and processed for 50 minutes at 250° F. (15-lb. pressure).

FROG LEGS

Small quantities of frog legs are canned commercially in the Gulf of Mexico and Mississippi River areas. As a rule, the hind legs only are canned, the meat from the fore legs and body being utilized in the preparation of specialty dishes similar to chicken à la king. Information is not available in the canning of "frog à la king," although a limited amount is canned commercially. Both common or "giant" bull frogs (*Rana catesbeiana*) and the smaller green frogs (*R. clamitans*) are used. The frogs are taken in the coastal bayous and river marshes by "torching" at night. A bright light is placed in the bow of a canoe or skiff. Frogs are attracted or dazed by the light so that they may be approached near enough to be taken by spearing, or in a dip net. Some are brought in alive. Frogs are said to be best from August through October.

The hind legs are separated from the rest of the body; the edge of the skin at the top of the legs is loosened, turned downward and pulled off over the toes, which are then cut off. The legs are soaked 15 minutes in a brine testing about 50° salinometer, after which they are washed thoroughly in cold water.

The legs are next drained and placed in a kettle with sufficient meat stock to cover. They are parboiled for 8 minutes, the stock is drawn off and the legs are packed in cans, usually No. 1 picnic (211 x 400), and squat (307 x 208) cans. The legs should be filled in carefully so that a good fill is obtained, with no large spaces. The fill-in weight of frog legs should be approximately 8 ounces for both sizes of container.

The cans are filled with the hot meat stock, leaving a headspace of $\frac{3}{16}$ inches, and are sealed immediately by closing machine without exhaust or mechanical vacuum seal. The process for both sizes is 45 minutes at 240° F. (10-lb. pressure). The product is water-cooled in tanks after processing.

CRAYFISH BISQUE

This specialty product is canned commercially in Louisiana and Mississippi, and is sold by grocers dealing principally in fancy foods. The packing method is an adaptation of the kitchen procedure. Each packer uses a secret formula, usually based on a family recipe. The following is typical:

10 lb. fresh water crayfish
6 large onions
6 oz. butter
½ cup olive oil
2 cloves garlic
1 tsp. minced parsley
1/16 oz. black pepper
6 slices dried bread
4 oz. flour
1 can tomatoes (No. 1 size)
1 can chicken consomme (No. 2 size)
3 qt. water
2 bay leaves
4 cloves
Cayenne and thyme, a dash

Ten pounds of fresh water crayfish are purged in a 30° salinometer brine for 15 minutes. They are then washed thoroughly and the shells are cleaned with a brush. The crayfish are boiled in 3 quarts of fresh water until they are red, or about 5 minutes. The heads are removed and cleaned; the tails are peeled and the meat is set aside. The claws are cracked with a hammer after which heads, claws and shells are put back into the water to simmer.

A dressing is prepared as follows: Six large onions are minced fine and cooked in 2 ounces of butter until soft but not yellow. Six slices of dried bread are soaked in water and the water squeezed out. The bread is mixed thoroughly with the onions and cooked 10 minutes over a low fire. The meat from the tails is chopped fine and added together with 1/16 ounce of black pepper, 2 cloves of garlic minced fine, and 1 teaspoon chopped parsley. The mixture is stirred well, cooked for about 10 minutes and salted to taste.

For a bisque, ¼ pound of butter is blended with ¼ pound of flour until the mass is smooth and cooked over a low fire until the mixture is brown. The contents of a No. 1 can of tomatoes and the strained liquid in which the shells have been simmered, is added gradually. A No. 2 can of chicken consomme is added, together with 2 bay leaves, 4 cloves and a dash each of cayenne and thyme. The bisque is simmered slowly for about 20 minutes.

While the bisque is simmering, about three-fourths of the heads are filled with the dressing and fried in olive oil for 3 to 5 minutes. About 12 heads are packed in each No. 1 picnic (211 x 400) cans or about 4 ounces by weight. The cans are filled with the hot bisque and sealed immediately. Accurate processing data are not available but it is understood that a process of approximately 45 minutes at 240° F. (10-lb. pressure) is used and that the pack is water cooled. The usual declared weight is 10½ ounces.

FISH ROE AND CAVIAR

Several types of fish roe are canned in the United States. While a variety of fish roe food products is prepared in Europe, particularly different types of caviar, not canned in the United States, canned roe products not found elsewhere are packed here and there are indications of a wider utilization of fish roe. All types of roe products sold in sealed containers for use as food or fish bait are included under this heading.

ALEWIFE (RIVER-HERRING) ROE

Alewife or river-herring roe is canned in Maryland, Virginia and North Carolina. The canning season extends from about April 1 to May 15, depending on weather conditions. The fish are taken by trap nets. The raw material is a byproduct of the Chesapeake herring salting industry. Only the roe is canned but experimental packs indicate that the milt would also make a good canned product.

The producers estimate that about 250 fish in a thousand are "roe" fish. In the beginning of the season, this number will yield about 1 bucket of fresh or "green" roe. As the fish mature, the amount secured increases to 1½ buckets, or in a few instances 2 buckets of roe. A bucket of roe generally weighs 20 pounds and should fill one case of 24 No. 2 short (17-oz) cans or twice that number of 8 Z-short (8-oz.) cans.

The roe is brought from the saltery to the cannery filling table, where it is freed from viscera and any roe not suitable for canning is removed since all roe must be packed while fresh. Roe stained by broken gall bladders cannot be used because of the bitter flavor. Very dark or immature roe must also be discarded. If swelling or "puffing" is observed, fermentation has set in and the roe must be discarded.

The canning of roe is intermittent, that is, sufficient roe must accumulate to justify starting the canning machinery. There may be a delay of several hours while the fish are being cleaned. Fresh water is poured on top of the cleaned roe, which is then stirred gently. After a short washing, the water is drained off.

The cans are filled by hand, the packers removing any remaining bits of entrails or other foreign material which have not been removed in the cleaning or washing processes. Packers should be closely supervised to ensure thorough cleaning and draining of the roe. The presence of viscera or bloody wash water in the container lowers the quality of the canned product. Since the roe swells when it is canned, a headspace of about 3/4 inches is left in the top of the container. The amount of "green" roe filled into the can varies from 13 to 14½ or 15 ounces by weight, the "cut-out" or drained weight after canning varies from 15¾ to 17¼ ounces for the No. 2 short can, in which the greater part of the roe is packed, and about half this weight for the 8 Z-short can. An average drained weight of 16 ounces is required by regulations of the U. S. Food and Drug Administration.

After filling, the cans are filled with hot brine from a perforated pipe. It is not the general practice to determine accurately the strength of the brine. Some canners recommend a brine of standard strength, that is, about 30° salinometer for the immature roe, decreasing to 20° for mature roe. A few packers use hot fresh water in place of brine. After brining, the cans are given a short exhaust of about 3 minutes at 210 to 212° F. In a few canneries the cans receive no exhaust.

The cans are then sealed, placed in metal can crates and processed in vertical retorts. The process varies in each cannery. No. 2 short cans are processed from 40 minutes at 244° F. (12-lb. pressure) to 60 minutes at 240° F. (10-lb. pressure). The 8 Z-short cans are generally processed 5 minutes less at the same temperature and pressure. Some canners water cool the cans immediately after processing, but others stack cool the pack in the warehouse.

During some slack period in the canning season, the cans are labeled and packed two dozen to the fiberboard carton. Demand for herring roe is almost entirely confined to the Southern coastal States. This appetizing product deserves a much wider market.

"DEEP SEA" FISH ROE

This product is the roe of groundfish, such as the cod and haddock; and is a byproduct of the trawl and line fisheries, obtained when spawning fish are caught. When the fish are cleaned, any roe is separated from the viscera and stowed in barrels in the hold, packed in ice.

At the cannery the roe is emptied into large trays with bottoms of wire mesh where it is drained and sorted. Dark colored roe and lobes of roe which may appear stale are removed. The roe must also be picked free from bits of viscera or other offal, especially gall bladders.

The cleaned roe is placed in bamboo baskets holding about 25 pounds each, and is washed in fresh water. The washed roe is ground and falls into a mixing machine. To a batch of approximately 200 pounds of roe, 40 quarts of water, in which 2 pounds of salt have been dissolved, are added and the batch is thoroughly mixed for 5 minutes. As the season advances, the roe is lighter in color and does not need as much mixing.

The mixture of roe and water drops into a reservoir tank from which it flows gradually into a smaller tank. The small tank is capped onto an evaporated milk filler which fills an average of 40 No. 1 tall cans a minute, to a net weight averaging 14 ounces. The filled cans are given a steam exhaust of about 8 minutes at approximately 200° F.

The cans are sealed automatically as they come out of the exhaust box, and drop from the seamer into can baskets. The process for No. 1 tall cans is 90 minutes and for 10-ounce flat cans 75 minutes at 240° F. (10-lb. pressure). The pack is water cooled after processing.

SHAD ROE

Shad roe is canned only in the Columbia and Sacramento River districts of the Pacific Coast. On the Columbia River the roe is obtained from shad taken by salmon fishermen, incidental to the catching of salmon, with most of the shad taken in the salmon haul seines, and, to a lesser extent, in salmon gill nets. The canning season extends from about April 1 to May 15 on the Sacramento River and from about May 1 to July 1 on the Columbia River.

The haul-seine fisheries are all within a short distance of the cannery so that fish are delivered within a very short time. The shad are usually piled in wooden fish boxes, but as a rule no ice is used. As the gill-net fishing extends over a larger fishing area, more time is required in transportation and the fish are iced. Shad taken in haul seines are usually delivered directly to the cannery. Shad caught by gill nets are delivered to buying stations in the fishing area, and later transported to the cannery.

The roe is separated from the viscera when the shad are dressed at the cannery. If the amount is not sufficient for canning, the roe may be placed in cold storage until a supply has been accumulated. The quality requirements for canning are exacting and exclude some shad roe which is considered of good quality for consumption when fresh. For canning, shad roe must be fully developed but not over-ripe. If it is too ripe, with the individual eggs ready to separate from the membrane, the canned product is watery and lacks flavor. If it is too "green" (under-ripe), the texture is too hard and flavor is also poor.

The first step in canning is to wash the roe thoroughly, removing all blood clots or veins, slime and the outer membrane. The fine membrane enclosing the individual lobes should be kept intact. Cleaning and washing requires great care in handling. The lobes should be kept whole and unbroken as much as possible. If the canned roe is badly broken, lower quality results. The loss in cleaning and washing is about 10 percent.

The drained roe is filled into ¼-, ½- and 1-pound oval cans. The ½-pound oval can is the size most widely used. The declared net weight is 3¾, 7¾, and 15½ ounces, respectively. The actual weight filled in is slightly heavier. The empty cans are lined with vegetable parchment paper and the roe must be laid in evenly, so that the appearance will be attractive when the can is opened. One-fourth ounce of salt is added per ½-pound oval can and a piece of vegetable parchment paper is placed on top of the roe. No brine, oil or sauce is used.

The cans may be sealed immediately after filling without heat exhaust or other means of obtaining a vacuum, or the lids may be clinched loosely and exhausted for about 8 minutes at 209 to 210° F. The cans are washed and scrubbed after sealing, and stacked in coolers.

There is a wide variation in processing. Some packers on the Columbia River, sealing without exhaust, process ½-pound oval cans for 90 minutes at either 220° F. (3-lb. pressure) or 240° F. (10-lb. pressure). The former process is also used by packers who exhaust before canning. Those who use the low pressure cook claim that a high process gives the canned roe an overcooked flavor and poor texture. The pack is air cooled. The processes fixed by the Bureau of Cannery Inspection, Department of Public Health, State of California, are: ½-pound oval cans 60 minutes at 240° F. or 40 minutes at 250° F., 1-pound oval cans 85 minutes at 240° F. or 65 minutes at 250° F. (15-lb. pressure). If the packer wishes to process at lower temperatures, the regulations permit a time of 120 minutes at 230° F. for ½-pound ovals, and 145 minutes at the same temperature for 1-pound ovals.

STURGEON CAVIAR

Caviar is prepared from the roe of the following species of sturgeon. On the Atlantic Coast, the common sturgeon (*Acipenser oxyrhynchus*) ; in the Great Lakes region, the lake sturgeon (*A. fulvescens*) ; on the Gulf Coast, the short nosed sturgeon (*A. brevirostrum*) ; on the Pacific Coast, the green (*A. medirostris*) or white (*A. transmontaus*) sturgeon; and in the Mississippi River valley, the shovel-nosed sturgeon (*A. scaphirhynchus*) are used. Roe from the last-named species is reported to make the poorest grade of caviar, The sturgeon are caught in large-mesh drift gill nets similar to salmon gill nets in construction and operation, and, especially in the Columbia and Mississippi River areas, on set- or trot-lines. A few sturgeon are taken in haul seines and traps. Gill-net fishing is most effective at night and in localities where the water is not clear. As the sturgeon are bottom feeders many of the sturgeon gill nets are operated as "sunken" gill nets, just scraping the bottom.

To make good caviar, the roe of the sturgeon should be "green" or immature. Fully developed roe, in spawning or near spawning condition, makes a very inferior product. The amount of roe obtained from an individual fish varies with size, species, and locality and may run from 10 to 70 pounds.

The fish should be gutted immediately and the roe freed from intestines and other viscera. Washing in fresh water is reported to lower the quality because such roe will not cure well. Icing the roe is claimed to have a similar effect. The roe must be landed and the cure begun, as soon as possible.

The roe is placed on a work table with a portion of its surface consisting of a ¼-inch wire mesh screen. A second finer mesh screen below this slants at a 45° angle into a large tub. Portions of the roe are rubbed lightly over the screen, so that the individual eggs are separated from the membrane and fall through the mesh onto the screen below, sliding gradually into the tub. Slime, blood and bits of membrane, drain through the second screen.

When the eggs have been drained they are mixed with salt. Caviar makers claim that the type of salt also affects the quality. In the United States "mild-cure" or "dairy-fine" salt is believed to be best but caviar makers with European experience claim that even this salt does not result in the best grade of caviar and that imported Luneberg salt should be specified. The amount of salt used varies with the training and experience of the curer, the condition of the roe and with the temperature. The average is about 8 pounds of salt per 100 pounds of roe (Hoffman; N. D.).

The cure should be mild since heavily cured roe will sell only in the cheapest trade. The curer distributes the salt as evenly as possible, then "rouses" or mixes salt and sturgeon eggs together carefully by hand. Paddles or other stirring tools are not recommended. The process of stirring is the most delicate operation in curing caviar. Only trained men of much experience can do it well. Cobb (1919) stated that both hands should be used to thoroughly mix the eggs and salt for 5 to 8 minutes, until a foam of slime appears on top of the egg mass. The mass is allowed to stand for 10 minutes and is then mixed again for a few minutes. By this time a copious brine should have formed so that the eggs will pour readily. If the operation has been properly performed a slight noise is perceptible when the mass is stirred, like small pieces of glass rubbing against one another.

The salted eggs are transferred to trays with a fine wire-mesh bottom (1/32-in. mesh), holding about 10 pounds each. These trays are placed between cleats on slanting boards set against a wall where they remain until the brine is completely removed. Sufficiency of drainage is determined by pressing against the under side of a tray. If cracks appear on top of the mass, the trays may be removed and the cure is completed.

The sturgeon caviar is packed in small kegs to a net weight of 100 pounds. Some canners line the containers with vegetable parchment paper before filling. The kegs are not headed immediately, but set in a cool place to stand for a few days until the caviar has settled. The headspace in the top of the keg is then filled with caviar and the top set in place. The kegs are usually shipped to New York City for final packaging and processing. Caviar should be shipped and held in chill storage at 34 to 36° F. If it is packaged and hermetically sealed unprocessed, it should be held by the retailer in refrigerated showcases.

While some of the sturgeon caviar canned in this country is of domestic origin, most of the pack is made from caviar imported from the U. S. S. R. The caviar is filled into cans holding 1½ to 2 ounces, 4 ounces, and 8 ounces and "nappy" glass jars with about the same net weights. The containers are sealed in a vacuum closing machine, then given a heat process. Publications stating the process as 50 minutes at 250° F. are entirely in error. Experimental packs indicate that heating under pressure will coagulate and harden the eggs to such an extent as to make the caviar entirely inedible. Accurate data on processing are not available at present. It is reported that caviar is pasteurized for about 60 minutes at 170 to 180° F., but this has not been verified.

WHITEFISH CAVIAR

Caviar is prepared commercially in the Great Lakes region from the roe of the common whitefish. (*Coregonus clupeaformis*). The principal manufacturing center is Port Washington, Wis. About 53 percent of the domestic catch is taken with pound and trap nets, 44 percent with gill nets and 3 percent with other forms of gear (U. S. Tariff Commission, 1933).

The roe is a by-product of the marketing of fresh whitefish. The skeins of roe are separated from viscera and blood, rinsed, then separated from the enclosing membrane as described in the preparation of sturgeon caviar. In fact the process follows this method, with the exception that as the eggs are much smaller, less time is required to absorb the salt, and allowance must be made for this in curing.

The whitefish caviar is colored in a caramel solution made from burnt sugar until it has acquired the almost black color characteristic of sturgeon caviar. It is packed in glass and tin containers of the same size as those used in marketing sturgeon caviar, and given approximately the same degree of pasteurization. The quality is usually excellent and the price is much lower than that of sturgeon caviar.

SALMON CAVIAR

Salmon caviar was originated about 1910 by a fisherman in the Maritime Provinces of Siberia, and the preparation is a modification of the sturgeon-caviar method (Cobb, 1919). This caviar has found a good market in the U. S. S. R. and other European countries, where it is known as "red caviar" to distinguish it from the sturgeon or "black caviar." Several attempts have been made to manufacture salmon caviar in the United States but only a few firms in the Pacific Northwest have been able to operate successfully on a commercial scale. Their product is marketed mostly in New York and other Eastern cities. One of the salmon canning firms operating in Bristol Bay also prepares salmon caviar, principally for export.

To be suitable for caviar, the eggs must be absolutely fresh, free from blood, of a clear color and good consistency. Large eggs do not make good caviar. Most salmon caviar is prepared from the roe of silver and chum salmon, the eggs of these species having been found to be best suited for this purpose.

The egg sac is slit and rubbed gently over a table stand with a top of half-inch mesh screen. This mesh is just large enough to let the eggs drop through, separating them from the membrane. The eggs fall onto an inclined screen of a fine wire mesh leading into a large shallow box. The eggs drain on the screen and finally slide into the box. The eggs are cured in brine testing 90° salinometer and usually made from fine mild-cured salt. The salmon eggs are occasionally stirred with a wooden paddle to ensure thorough mixing and equal absorption of brine. The brining time varies with the season, temperature and humidity; size, consistency and freshness of the eggs. The time required is believed to vary from 20 to 45 minutes. The packers determine the sufficiency of cure by noting the change in consistency of the eggs. The interior must coagulate to a certain jelly-like consistency, but the egg must not be shrunken. The eggs are dipped from the vat, placed on wire-meshed screens and drained overnight or for a period of about 12 hours.

After draining, the eggs are filled into small kegs holding about 100 pounds lined with vegetable parchment paper. The kegs are covered and allowed to stand until the eggs settle. The head-space caused by settling is then filled up with more caviar, the keg headed and put in chill storage at 34 to 36° F. until shipped.

The kegs are repacked in jars and tins by large wholesale dealers in the eastern part of the United States. "Nappy" glass jars holding 2 to 4 ounces are probably the most widely used containers, though salmon caviar is also packed in glass tumblers holding 6 ounces and tin cans with a net weight of 2 to 7 ounces. Tin containers are usually of the "key-open" type, inside-enamelled and are lithographed. Previous discussion on pasteurization or preservation of caviar by heat applies also to salmon caviar. Experimental packs of salmon caviar processed at temperatures between 212 and 240° F. were made absolutely inedible by processing, losing color and acquiring a hard, rubbery texture.

Both glass and tin containers are carefully cleaned before use, filled to the specified net weight by hand and sealed in vacuum closing machines. To secure the maximum preservation the containers should be held at temperatures not greater than 40° F. or less than 29° F., when they may remain in good condition for a year.

SALMON EGGS FOR BAIT

The first commercial use made of salmon roe was the preparation of "bait eggs" for catching trout and other game fish. This industry began about 35 years ago. A number of firms in the Columbia River and Puget Sound districts are now engaged in packing bait eggs and find a ready market for their product.

The roe must be fresh and not too "green;" that is, the eggs must have a firm consistency and separate readily from the enclosing membrane. They must also be of good size and clear in color. Each packer of bait eggs uses a process developed by himself. The method described is not used by all packers of bait eggs. However, it is known to have been used commercially and will at least serve as a basis for experimentation. The first steps in preparing bait eggs are almost identical with the first stages in the preparation of salmon caviar. The egg sacs are split open and hot water is poured over the roes which separates most of the eggs from the membrane, and the remainder are freed by rubbing over a wire mesh screen. This method is quicker than screening the entire mass but should not be used except by skilled bait egg packers, as over exposure to hot water will damage the texture of the eggs and make them unfit for use.

After draining for a few minutes, the eggs are placed in a solution of salt, sugar and coloring material. The proportions of salt to sugar vary with different packers and may range from 1 part sugar and 3 of salt to 1 part sugar and 9 of salt. The coloring material used is one of the analine dyes in several shades of red, such as Sherwin-Williams 3-R. or Erythrosin. The curing solution will test 80 to 90° salinometer and the eggs are left until "cured." The cured eggs must have a firm consistency so that they cannot be easily stripped from the hook but must not be shrunken, hard or rubbery.

The color of the eggs depends on the strength of the dye and length of time the eggs are left in the dye-pickling brine. Some markets desire a very brilliantly colored egg, while others require a pale shade, resembling the natural color of the fresh egg. It has been the tendency among fishermen to insist that the first shade of color used for bait eggs in their particular locality is the only one that will attract fish. For a medium shade, the eggs are left in the brine about 30 minutes.

After the eggs are sufficiently colored and cured, they are drained on wire-mesh screen-bottom trays and packed in small glass or tin containers. The most popular container is a glass jar with a two-piece screw top holding 3½ ounces. The tin can most widely used is a lithographed container of the same net weight. Sometimes a solution of glycerine and preservative is added before sealing the containers, but packers of bait eggs claim that if the eggs have been properly prepared this should not be necessary. Bait eggs will remain in good condition up to a year, if kept in a cool dry place. However, if the jar is opened mold will start growing.

Preservatives are added to the curing solution, usually sodium benzoate, about 1 percent, if the eggs are to be sold in warm climates. The glycerine preservative solution may contain 5- to 10-percent formalin. The eggs will harden and turn white if the formalin solution is too strong. Formaldehyde is legally prohibited for use as a bait egg preservative in some localities on the grounds that it is poisonous to fish life. There are no scientific data to support this contention.

In addition to single eggs, "cluster eggs" are marketed. These are portions of roe with membrane and eggs adhering. They are used principally in fishing for steelhead trout. Cluster eggs are manufactured from small "green" roes, still partially undeveloped. The clusters are washed, then placed in a brine as described in the preparation of single bait eggs. Preservatives are frequently added in this brine, either formalin, hexymethylamintetramin (urotropin), or sodium benzoate.

The time required for curing is variable and is determined by testing the consistency of the eggs. As a rule it is somewhat longer than that required for the preparation of single bait eggs. When the pieces of roe are cured, they are drained and packed dry in ½- or 1-pint glass jars. Under ordinary conditions of temperature and storage, "cluster" eggs will remain in good condition from 6 to 12 months.

CANNED PRODUCTS HERMETICALLY SEALED BUT NOT PROCESSED

A number of products are packed in hermetically sealed glass or tin containers under vacuum which have not been "sterilized" or "processed" by heat, but which are generally included among canned products. Preservation of these products is possible only for limited periods, which may be sharply reduced by unfavorable conditions of storage and handling. These products depend for preservation on the curing to which they are subjected previous to packing and on subsequent storage at low temperatures. The tin or glass container simply serves as a method of packaging, superior to containers previously used, and has very little or no preservative effect. It is not possible under present methods to preserve some of these products for longer periods by using a heat process. For example spiced herring are made tough and fibrous in texture, unpleasant in flavor and discolored by cooking or processing. Products such as oysters, crab and shrimp meat can be and are processed, but when they are sold unprocessed in hermetically sealed containers it is because the market for which they are intended demands the flavor of the "fresh" product.

ANCHOVIES

Two types of anchovies are packed, Spanish or Italian anchovies, and the Norwegian or Swedish anchovies. The former are true anchovies, while the second variety is made from the brisling or sprat. The methods of cure also differ. Since few anchovies are cured locally, those packaged in this country are imported, usually in wooden kegs holding about 100 pounds each. They are repacked in glass and tin containers holding from 1 to 8 ounces. Apparently more glass than tin containers are used for this purpose in the United States. Most anchovies imported in individual containers are packed in tin. Imported cans are not standardized, many odd-sized containers being used. Most of these are "flat" or "square" pressed tins of the type used for sardines or kipper snacks.

SPANISH OR ITALIAN ANCHOVIES

Spanish or Italian anchovies are cured by a process which depends on fermentation to give the product the desired flavor. Curing varies in details among different packers, but the following method is representative: Fresh anchovies are gutted and headed by twisting the heads off, the workers using their fingers. The visceral material is removed, attached to the heads. The fish are then salted down in large hogsheads or vats, using 40 to 50 pounds of salt to 100 pounds of fish. The hogsheads are left standing in the sun, or the vats are subjected to a temperature of 80 to 90° F. for several hours each day. At the end of 3 or 4 months, fermentation should have progressed so that the flesh assumes a red color and acquires the desired flavor. The fish are then removed from the brine and pressed to remove excess moisture and oil.

In some instances the anchovies are cured in tanks for about 3 months with 50 pounds of salt per 100 pounds of fish. After this they are taken from the heavy brine and resalted in hogsheads with 25 pounds of salt per 100 pounds of fish. The hogsheads are left in the sun until the anchovies have acquired the desired color and flavor. Ocher may be added to the brine to improve the color.

NORWEGIAN OR SWEDISH ANCHOVIES

Norwegian or Swedish anchovies are flavored with salt and spices and the curing is not a fermentation process. Various spice mixtures are used but the following process is typical. From 25 to 30 pounds of sprats are placed in a brine made of 4½ pounds of Liverpool salt and enough water to cover, for 12 hours, and are then laid on a screen to drain. The following quantities of spices are used: 2¼ pounds of Luneberg salt, 3 ounces of pepper, 3 ounces of allspice, ½ ounce of cloves, ½ ounce of nutmeg and ½ ounce of cayenne pepper. All are well pulverized or ground and mixed together. The sprats are well stirred up with half of these spices in a large container in which they are packed and left for 14 days. They are then packed in layers, backs down. Some of the remaining spice mixture is scattered between each layer, with pieces of chopped bay and cherry leaves. On the bottom and on the top of the containers two whole bay leaves are laid. The brine formed in the larger container is used to fill in the smaller containers after packing. During the first few days after the containers are closed they must be rolled about and inverted at least every other day (Hoffman, N. D.).

Tin containers are preferred to wooden kegs not only because the latter are often leaky, but also because the airtight seal in the former permits a longer period of preservation.

According to another formula fresh brisling are placed for 12 to 24 hours in a strong salt brine, drained and dried on a screen, and are packed in layers in small kegs. To each 40 pounds of fish, 2¼ pounds of Luneberg salt, 7 ounces of pepper, 7 ounces of allspice, 7 ounces of sugar, 1⅛ ounces of cloves, 1⅛ ounces of nutmeg, and 1⅛ ounces of Spanish hops are added. The spices are coarsely pulverized and mixed with the salt. At the top, bottom and in the middle of the keg, several bay leaves are laid. The kegs are packed very tightly and rolled about or inverted daily for 14 days. The anchovies may be repacked in tins in 14 days in summer, or 4 to 8 weeks in winter.

CODFISH

Fresh or canned fish cannot be substituted with complete satisfaction in certain favorite dishes where salt cod has always been used. But the modern grocer hesitates to handle salt cod because the distinctive odor which develops after curing, under ordinary conditions of handling, will drive customers away. Furthermore the deterioration, together with the drying, yellowing and crystallization of salt on the surface, which occur while the cod is being held for sale, lowers the quality and decreases the margin of profit.

The use of hermetically sealed vacuum pack containers removes the odor objection and results in salt codfish reaching the retail market with the flavor, color, texture and moisture content of freshly cured fish. No "sterilization" process is used, therefore the period of preservation is limited. This method was first used commercially on the Pacific Coast, but has also been introduced in the New England salt fish industry.

Freshly cured salt cod is graded for quality, only the best grade of fish being used. The selected fish is skinned, boned, and cut in container length pieces. At the filling table workmen weigh out the salt fish in one-pound lots, passing it to packers who form it into cylinders. Each cylinder is rolled in a sheet of vegetable parchment paper, the ends of paper are folded over to make a neat package, which is filled into a No. 1 tall can, with "C" enamel lining, seafood formula. The filled cans are sealed under vacuum, usually not more than 12 inches. The sealed cans do not require washing, though they may be wiped with a cloth. After labeling, 1 dozen cans are packed to a fiberboard carton.

Another hermetically sealed vacuum pack salt codfish is shredded cod. This is made by taking small pieces of good quality fish, nostly trimmings from packaging salt cod. These bits are shredded by machine, then filled into glass containers of the "tumbler" ype with a capacity of 4 ounces net weight. The containers are itted with metal tops and sealed in a vacuum closing machine. This product should not be placed in a strong light or oxidation ind loss of flavor will occur. It is used principally for making odfish cakes.

SMOKED HERRING

A small but increasing amount of skinned and boned hard smoked herring is packed in hermetically sealed containers every year, selling principally to the delicatessen trade where it is sold as an hors d'oeuvre or "cocktail relish." This pack is made in Maine from herring cured in that State or imported from Nova Scotia.

The method used in smoking "hard cured" herring is described fully by Tressler (1923) and Stevenson (1898). The herring are cured a minimum of four weeks to a moisture content of 5 percent. Temperatures higher than 80° F. should not be used and many smokers prefer a temperature of about 62° F.

Boning and skinning the smoked herring may be done at the smoke house, or it may be "farmed out" on a piece work basis in nearby homes. The heads, bellies and tails are clipped off with scissors or removed by knives, the viscera are pulled out and the herring split in half. Workers, usually women and children, remove skin and bones with their fingers. The skinned and boned fish are cut in strips about ¼ inch in width and are packed vertically in vacuum sealed glass tumblers, to a net weight of about 4 ounces. Like the shredded cod packed in glass, the jars are liable to oxidation if left in a strong light. This product is not processed, but has been cured to a degree where preservation is almost unlimited under favorable storage conditions.

SMOKED SALMON

Mild-cured chinook salmon is used in the majority of instances for the preparation of canned smoked salmon, although some fresh salmon, lightly salted, is used in Norway, and some mild-cured pink salmon in Japan.

In preparing smoked salmon from mild-cured fish, the sides of salmon are taken out of the tierce and soaked overnight in a tank of fresh water, changing the water 2 or 3 times. When properly freshened the salmon are washed with a stiff bristle brush, to remove all traces of blood, slime, or encrusted salt.

The salmon are often drained by "water-horsing," that is, they are placed in a pile, flesh side down, while weights are placed on top of the heap to further increase the pressure and expel the excess water. After draining, the sides are trimmed of any ragged edges and wheeled to the smokehouse.

Salmon smoked for canning is given a "hard cure," requiring much more time than the usual method. After the smokehouse has been filled, a fire is started in the pit below and for some hours the fish is smoked over a clear fire with the ventilators of the smokehouse open so that the moisture will escape. Otherwise the humidity would be increased to such a point that it would collect on the fish, causing them to "sweat."

The ventilators in the top of the smokehouse are closed and the fire is smothered with sawdust when there are no indications of surface moisture, and the sides of salmon have a thin glistening film or pellicle, or at the end of about 48 hours, and a dense smoke is created in which the salmon are cured for an additional period of 3 to 7 days.

The length of the smoking period varies with the locality, type and size of smokehouse, temperature used in smoking, humidity and outside temperature. Exact data as to smoking temperatures giving the best results are also lacking. As a rule the temperature should not exceed 80° F. and in general should be slightly lower. If too much heat is given off by the fire, the product will be partially cooked, will soon spoil and will not have the desired texture.

Alder wood is used in smoking salmon on the Pacific Coast, but almost any non-resinous wood such as maple or beech gives satisfactory results. Oak and hickory are favorite fuels among salmon smokers in the Atlantic Coast area of the United States. European packers of canned smoked salmon generally use beech or oak.

When the cure is completed, the smokehouse doors and ventilators are opened. After the smoked sides are sufficiently cool, they are skinned and cut in transverse slices showing as much as possible of the striations of the flakes of flesh, making a very attractive appearance. The slices are thin, averaging about 40 to the pound. While salmon has been sliced by hand until recently, automatic slicing machines have been found more efficient.

Hand packers fill the strips of sliced salmon into "quarter oil" cans to a net weight of 3¾ or 4 ounces. A small quantity of olive oil is added to each can. The filled containers are then sent through can closing machines which may or may not be of the vacuum sealing type. The hermetically sealed cans are cleaned, labeled and packed in cartons for shipment. No "cook" or "process" is given.

While this product is not as perishable as ordinary smoked salmon, it will not "keep" indefinitely and should not be exposed to unfavorable storage conditions. The maximum preservation period is secured by storage in refrigerated show cases. Occasionally a European packer will add hexymethylamintetramin (urotropin) as a preservative. The use of this preservative is not permitted under the regulations of the U. S. Food and Drug Administration, or in most other countries. Chemical preservatives of the permitted types and in amounts allowed have not been found effective or desirable.

SPICED HERRING

Spiced herring, as packed in the United States, is prepared entirely from fish cured during the fishing season, held in storage and manufactured into spiced herring products as the market requires. Herring may be specially cured for this product, or "Scotch cure" or "Labrador" salt herring may be substituted. Herring not specially cured for spicing is reported to have a shorter period of preservation, is darker in color, lacks flavor, and is tougher and more fibrous in texture. Such raw material is used when the stock of specially cured herring is exhausted, or in places where it cannot be secured.

Most of the specially cured herring is prepared from alewives or river herring (*Pomolobus pseudoharengus*) in the Chesapeake Bay area. A variety of curing methods is used of which the following is typical: The cut herring are cleaned thoroughly, with special attention to removal of the kidney, the dark streak along the backbone. The fish are rinsed in fresh water, and placed in a curing tank where they are covered with a brine testing 80 to 90° salinometer, which contains 120-grain distilled vinegar to an acidity of about 2½ percent. They are left in this brine until the salt has "struck through" the flesh, but they must be removed before the skin starts to wrinkle or lose color. The length of cure depends on the judgment of the curer and varies with the temperature conditions, freshness and size of the fish. The average length of cure is reported to be 5 days. Various sources of information give curing times running from 3 to 7 days.

As soon as the herring have absorbed sufficient salt, they are packed in barrels. These are often secondhand, previously used for soda fountain syrup. The barrels are headed up, filled with a salt-vinegar brine testing 70° salinometer and shipped to marketing centers such as Chicago or New York for final manufacture.

When the herring are received at the manufacturing center they are cut in cross sections if they are to be packed as "cut spiced" herring, sliced into fillets and boned if they are intended for "rollmops," and the backbone is removed but the sides remain joined, if they are to be prepared as "Bismarck" herring. The herring are repacked in kegs which are filled with a solution of distilled vinegar diluted with water to 3 percent acidity, and containing sufficient salt to test 35° salinometer. The kegs are then put into cold storage at 34° F. to be held until required.

The final process of manufacture is begun by soaking the herring in a tank of cold water from 8 to 10 hours. They are then removed, drained and placed in a solution of vinegar, salt and water for 72 hours. This solution is made up in the proportion of 1 gallon of 6 percent white distilled vinegar to 1 gallon of water and 1 pound of salt.

CUT SPICED HERRING

Sliced herring are then packed in 8-ounce tumblers, or in 16- or 32-ounce jars, with whole mixed spices. The amount of spices added to each container is approximately 2 teaspoons to an 8-ounce tumbler, 3/4 tablespoon to a 16-ounce jar, and 1½ tablespoons to a 32-ounce jar. A slice or two of onion, a slice of lemon, or a strip of canned pimiento may be placed around the sides, depending on the preference of the individual packer. Each container is then filled with vinegar diluted to 2½ percent acidity, containing 1 pound of sugar, ¼ pound of salt, 5 drops oil of cloves, 5 drops oil of allspice, and 5 drops oil of cardamon per gallon of solution. The spice oils are usually added to the sugar before dissolving it in solution, as the spice flavor is then more evenly distributed.

The amount of spice oils and variety of spice flavors used, may be altered to suit the taste of the packer or his market. This formula is typical rather than standard. The jars are then vacuum sealed, wiped clean, labelled, and packed 1 or 2 dozen jars to the fiberboard carton. Length of preservation depends on care in manufacture and storage. If held under refrigeration this product may remain in good condition for 12 months.

ROLLMOPS

The method of packing given previously is followed, the only difference being that fillets are rolled around a small piece of dill pickle or bit of onion, and fastened with wooden tooth picks.

BISMARCK HERRING

Boned and trimmed fish are packed vertically in glass containers of various sizes, such as 8-ounce tumblers, 16- or 32-ounce jars, and prepared as outlined for the final packing of cut spiced herring.

OYSTERS

The packaging and distribution of fresh shucked oysters in individual sealed containers has recently become an important factor in the oyster industry. Fresh shucked oysters are packaged in individual retail size containers on the Atlantic Coast to some extent, but this is primarily a development of the Pacific Coast oyster industry.

Four types of sealed containers are used: (1) Hermetically sealed tin cans, preferably in pint and half-pint sizes; (2) friction top cans in the same sizes; (3) glass bottles of the milk bottle type in quart and pint sizes, with the regular milk bottle caps; and (4) waxed pasteboard cartons, in quart, pint, and half-pint sizes, either of the ice cream carton or cup type. Bottles and pasteboard containers are today practically limited to local distribution by problems of shipping and handling. At present the hermetically sealed container is the type recommended for use in the development of a larger retail market for fresh oysters.

Troubles such as swollen cans and deterioration are encountered at times in packaging and distribution of fresh oysters in hermetically sealed containers. This may be due to lack of knowledge of the limitations in keeping quantities of fresh shucked oysters. McConkie reports that "an incomplete knowledge of storage temperatures necessary to preserve a satisfactory quality for an adequate period of time to permit distribution and consumption. It is our opinion that producers, distributors, and consumers have all been guilty of mishandling in some instances. Probably there will always be an occasional consumer complaint resulting from carelessness on his own part, but the major improvements calculated to overcome the present difficulties must be made in the producing plants and their distributive agencies."[20]

Discussion of the growing and harvesting of oysters would involve needless duplication as this information is available in other publications, to which the reader is referred; Tressler (1923) and Fiedler (1936). The packer must keep constantly in mind that the oysters must be in good marketable condition with firm, sound meats. On the Pacific Coast some oysters in certain beds have been found to be in spawning condition during the latter part of October. Oysters taken from various coastal areas of the Atlantic Coast may be still "thin" and "poor" during the early fall if growing conditions have been unfavorable.

The oysters should be unloaded immediately on arrival at the plant, and stored in a chill room at temperatures between 40 to 45° F. until they can be shucked. This is done in Pacific Coast shucking plants, but is not common practice on the Atlantic Coast. An alternative method, serving the same purpose is to hold oysters in sink floats near the opening house, shucking the mollusks immediately on removal from the float. Oysters in shells should not be allowed to stand in the direct rays of the sun, or be exposed to the open air.

In the more up-to-date plants packaging oysters in hermetically sealed containers, shell oysters are removed from chill storage to the shucking room only as required by the openers. As the product is not processed it is subject to contamination so that extreme care in plant sanitation and the various production steps is necessary to reduce bacterial contamination to a minimum.

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[20] McConkie, J. E. Handling, Packaging and Distribution of Fresh Oysters. 9 pp. Bull., Research Department, American Can Co., Inc., Portland, Oregon.

In a representative plant packing fresh oysters in hermetically sealed containers, the shucking room is built of concrete, with a continuous expanse of window on two sides, amounting to about one-third of the wall area. The floor is waterproofed concrete, with numerous drains. The benches, also waterproofed concrete, run along two outer walls just below the windows and are divided into individual working spaces, each large enough to hold a bushel of shell oysters. Each space is equipped with an electric light, shaded and hung so that the workers' eyes will be protected from glare, and throwing the maximum of light on the working space. All pans, shucking cups, buckets and similar utensils are made of non-corroding metal.

The oysters should be shucked into small containers preferably not larger than quart size cups so that the meats may be collected frequently. Puget Sound oyster men favor shallow pans holding about one pint. However, the Olympia oyster is smaller than either the eastern or "Pacific" varieties, so that a longer time is required to shuck a given quantity. The shucked meats are washed immediately, preferably in small batches, for more thorough washing, to reduce exposure to the air and possible contamination.

On the Pacific Coast the meats are usually washed by hand, stirring a quantity of meats in an equal amount of water and draining them in colanders. On the Atlantic Coast, the oysters are "blown" in shallow tanks, fitted with perforated false bottoms. The tank is provided with a water pipe and a compressed air line enters the bottom. Ice may be added, especially if the temperature of the water is higher than 45° F. Chilled oysters should not be washed in water at temperatures of 50 to 60° F., making it necessary to rechill the meats.

As the oyster meats are placed in the blower the compressed air is turned on, aerating the water and agitating the meats gently, until bits of shell, sand, dirt, or other waste are thoroughly removed. The use of a 3-percent brine for washing is required by law in some localities, to prevent "bloating" or swelling which occurs if the meats are left in fresh water over long periods of time.

After washing, the oyster meats are allowed to drain until all surplus moisture has been removed. In some plants they are then graded for size. The oysters should be inspected for quality before packaging, and any discolored or cut meats removed.

Filling must be carefully controlled. The meats are hand filled into "sanitary" type cans. The cans are not vacuum sealed and the slightest overfilling causes the ends to spring out, giving the impression of spoilage, so a ¼-inch headspace must be left in filling. Springers are most apt to occur in ½-pint cans. The can lids, which should be equipped with gaskets, are sealed on the cans by semi-automatic closing machines.

The packaged oysters are chilled immediately after sealing the cans. Air cooling in chill rooms at 32° F. is used by some packers, but it is regarded as a better practice to submerge the containers in tanks of ice water at 32° F., or to pack them in bins of finely crushed ice. Friction top cans cannot be placed in ice water, but should be packed in finely crushed ice. The rate of heat extraction is much slower if the pack is air cooled. After chilling, the sealed containers should be held at 32° F., either in chill rooms or in crushed ice until they are shipped.

Some packers do not ice the shipping containers for short distance shipments or for local distribution, but it is good practice to ice all shipping containers, using an amount of ice one-half the weight of the product. Long distance shipments may require a larger amount of ice, and should be re-iced in transit.

Producers of fresh canned oysters are finding it advisable to educate retailers, hotels, restaurants and individual consumers to the fact that the oysters must be kept at temperatures as near 32° F. as possible, keeping them in mechanical refrigerators or in crushed ice, until they are prepared for the table. The cans should never be displayed in show windows or elsewhere than in refrigerated show cases.

Fresh oysters packed in hermetically sealed containers have a period of marketability of about one week after packing. If packing conditions and storage temperatures approximate the ideal, they may be held as long as 10 days or 2 weeks and still show very little loss in quality (McConkie; N. D.)

CRAB MEAT (PACIFIC COAST AND ALASKA)

A considerable portion of the production of Pacific Coast "Dungeness" crab is marketed as fresh cooked meat, packed in hermetically sealed tins and shipped in ice. This is known as "cold-pack" crab meat. If the supply is larger than the market can absorb at the time it is frozen and held until needed.

The Dungeness crab-canning procedure is followed up to and including the brine dip. The drained meat is sent to the retort in open trays. Here it is steamed for about 20 minutes, gradually bringing up the temperature from 212 to 220° F. The trays of steamed meat are placed in racks and allowed to cool over night. In the morning the meat is packed in No. 10 cans lined with vegetable parchment paper, to a net weight of 5 pounds, or in 1- or 2-

pound lithographed cans. Body and leg meat is filled into the cans in equal proportions. The cans are sealed without vacuum, packed in finely crushed ice, then shipped and held under refrigeration. The market for Dungeness cold pack crab is largely in the Pacific Coast region, although some is shipped to the Middle Western and Rocky Mountain States.

SHRIMP MEAT (ALASKA)

The production of non-processed cooked shrimp, packed in hermetically sealed containers, is at present confined almost entirely to Alaska. The otter trawl and haul seine used in the shrimp fisheries of the Atlantic Coast have been found ineffective to date in Alaska, as the shrimp are taken at depths of 50 fathoms or more, and the bottom is very irregular. The beam trawl in sizes ranging from 16 to 60 feet in beam is the only type of fishing apparatus used in this industry.

The gear has been mechanized so that it can be handled by a crew of 2 men. The trawl is dragged over the bottom at the rate of from ½ to 1½ miles per hour, according to depth of water and type of bottom. The length of the haul depends on the extent of the fishing area and the amount of debris collected in the trawl. When it is thought the trawl should be lifted, the boat is stopped and the net is hoisted to the surface. If a soft or muddy bottom has been fished, the trawler gets under way again and tows the gear until the catch is well washed.

The slack is hauled in until the catch has been concentrated in a small portion of the bag, when the shrimp are removed by a large dip net and deposited on a cleaning table where they are separated from shells, seaweed, "scrap" fish and other debris, and raked into large boxes with a capacity of approximately 200 lb. net. Ten boxes is stated to be a good day's catch.

As soon as the catch is unloaded, the whole shrimp are dropped into tanks of water held at temperatures of 210 to 212° F. by jets of live steam. The shrimp are boiled for about 5 minutes or until the meat has shrunk sufficiently so that air spaces appear between shell and meat. When sufficiently cooked, the shrimp are dipped from the tank onto shallow trays with wooden sides and wire mesh bottoms. These trays are set in racks until the shrimp are dry and cool. Shrimp are usually boiled late in the day and left in the racks overnight.

After picking, the meat is first washed in fresh cold water, then dropped in a saturated salt brine, where it is held for 3 minutes. The brined shrimp meats are again cooked in a retort for 3 minutes at 220° F. After cooking, the meat is again piled in trays and taken to the racks, where it is generally left until the next day to dry and cool. The meat is then passed through a fanning machine, which blows out all bits of loose shell and antennae which have not been previously removed.

The meat is filled in No. 10 cans, lined with vegetable parchment paper, to a net weight of 5 pounds. The filled cans are hermetically sealed without vacuum. The cans are packed in finely crushed ice and shipped south by steamer.

This shrimp is known as "fresh shrimp meat" or sometimes as "cold-pack" shrimp. It is purchased by retail fish markets and by the hotel and restaurant trade. If demand is slow, surplus cans of shrimp meat may be frozen at approximately –5° F. and held in storage at about 5° F., until marketed. The shrimp remain in good condition and are apparently unaffected by freezing.

SEAFOOD COCKTAILS

Prepared seafood cocktails are packed in all important fisheries centers of the Pacific Coast and Rocky Mountain States. The varieties marketed are clam, Olympia oyster, crab and shrimp.

This product is manufactured on a home or kitchen scale and no two packers follow the same formula. Glass containers only are used, bottles with a net capacity of 4 and 6 ounces. The bottles are specially designed for the purpose with a wide mouth and short neck. Some cocktails are occasionally packed in flat sided 8-ounce preserve jars, but this is not regarded as a good practice. Such jars do not make as good an appearance, are harder to fill, seal and empty.

The principal factor in preparing seafood cocktails is the sauce. Each packer has developed his own formula. Numerous experiments are made until the desired flavor and maximum length of preservation are obtained. A bottled cocktail sauce requires a higher proportion of acid, spices and salt, and a lower moisture and sugar content than a sauce prepared for immediate use. The basis of a cocktail sauce is tomato ketchup. Specifications for a good quality sauce call for the highest grade of prepared ketchup obtainable, a strictly fancy grade, not sweet, which is usually purchased in No. 10 cans, 6 to the case.

Cocktails are packed in quantity during the winter and held for sale but at other times they are usually packed only on order. It is customary to allow a rebate for return of empty containers.

Only the freshest seafood should be used. Crabs and shrimp are cooked and the meat is made up into cocktails immediately, as use of meat cooked some time previously is believed to reduce length of preservation and to lower the quality of the product. Clams and oysters are shucked immediately before packing. Oysters going into cocktails should show absolutely no "bloat." "Little-neck" or "cherrystone" clams give better results than the larger sizes, because of superior flavor and tenderness. The small size of Olympia oysters secures a more even blend of flavor with the sauce. Cocktail makers also claim the flavor of these oysters to be superior. Crab meat should be divided into small pieces so that it will mix well with the sauce, but should not be shredded finely or the crab flavor will be lost. Small shrimp are preferred for cocktails and if large shrimp are used they should be chopped into two or more pieces.

The seafood portion of the cocktails is filled into the bottles which are sterilized just before use. Containers should be dry when filled. The average amount of crab and shrimp meat placed in each 4-ounce container is 1½ ounces, while the 6-ounce size receives 2½ to 3 ounces. Some packers increase the amounts to 2½ and 3½ ounces respectively, but as the margin of profit is small and competition is keen, this is usually done only in markets catering to the higher priced trade. Clams and oysters are filled in by count. The number of Olympia oysters to a 4-ounce cocktail runs from 4 to 8. A good cocktail should contain at least 6 oysters.

The cocktail sauce is then added in amount sufficient to fill the containers. Bottles are hermetically sealed, in the majority of cases, with a crown type seal, though a screw top lid is occasionally used. Vacuum sealing has been tried, but is at present almost entirely abandoned. Small amounts of clam or oyster juice may be used to dilute the ketchup and replace part of the acid, in making up clam and oyster cocktails.

Fresh cocktails remain in good condition about 10 days under ordinary conditions of merchandising. This may be increased to about 30 days, if the cocktails are held at 34 to 36° F. If a maximum length of preservation is desired, cocktails should be retailed from refrigerators or refrigerated showcases. Retailers should be cautioned that exposure on shelves or on top of showcases, in brilliant sunshine, or placing the containers near artificial light, hastens spoilage.

Some cocktails are pasteurized for 1 hour at 170° F. While length of preservation is increased, the product is regarded as inferior to fresh cocktails. Attempts to obtain commercial sterility have not been successful to date. Processing at temperatures 212° F. or higher, caramelizes the sauce and makes the seafood portion of the cocktail hard and fibrous.

COCKTAIL SAUCES

A successful manufacturer must experiment to determine the type of cocktail sauce best suited to his local trade. One of the packers of cocktails also markets a prepared sauce for sale to packers in other areas. The following sauce formulae are typical, but are presented only for guidance:

SAUCE NO. 1

6 cups tomato ketchup
2 cups horseradish
4 cups lemon juice
Salt, celery salt and tabasco sauce to taste

Beat the ingredients together in an electric mixer, until they are well blended. This applies to all sauces.

SAUCE NO. 2

3 cups tomato ketchup
1 cup Worcestershire sauce
2 cups horseradish
1 cup lemon juice
⅛ cup red pepper sauce
Salt to taste

This sauce is more pungent than No. 1 and may be too peppery for some people.

SAUCE NO. 3

2 cups tomato ketchup
2 cups lemon juice
1 cup horseradish
1 cup Worcestershire sauce
1 cup vinegar
2 teaspoons salt
2 teaspoons white pepper
1 teaspoon tabasco sauce

In using Sauce No. 3, the shrimp or other seafood is marinated for 2 hours before filling into the containers, in a solution consisting of the vinegar and one cup of the lemon juice listed in the ingredients, together with the pepper and salt. The other ingredients are mixed well, then poured over the seafood when it is filled in the container.

SPOILAGE IN CANNED FISHERY PRODUCTS

Certain changes which occur in canned products after sterilization or processing are beneficial and improve the quality of the product. Canned salmon eaten immediately after packing may taste "flat" as if insufficiently salted or the taste may be excessively salty, depending on the portion of the contents tasted. Other cans of the same pack sampled after a short storage period will taste sufficiently salted. The salt added in filling requires time for an even and complete distribution throughout the contents. Sardines or tuna packed in oil may taste "raw" or "flat" if sampled immediately after canning. The oil in which these fish are packed is only absorbed gradually.

There are other changes which affect the product adversely. Strictly speaking, many of these changes should be called deterioration rather than spoilage. The commercial value of the food is lowered and it may be unappetizing but not absolutely inedible. However, since the product is of lower grade and frequently unmerchantable, it is considered spoiled. We have then two general types of deterioration in canned products; first, that due to physical and chemical changes, and second, spoilage brought about through micro-biological action. It is necessary to determine the type and cause of spoilage in order to determine whether the product was properly prepared, of suitable raw material, or to locate faults in materials or methods.

CLASSIFICATION OF SPOILED CANS

There are certain easily identifiable evidences of spoilage in canned foods which have been classified as follows:

Flipper.—A can which may be normal in appearance, but if one end is struck on a box or table, the other end becomes convex, though the convexity may be pressed down again. A flipper is the initial stage of a swell, but may also be caused by overfilling or lack of vacuum.

Springer.— A can having convex or bulging ends, which may be pressed flat again with the fingers, but will spring out again after pressure is released.

Swell.—A can with badly bulged ends resisting pressure with the fingers or if the ends are pressed down, they spring back immediately on the release of pressure.

Flat sour.—A can whose contents have been spoiled by micro-biological action without the formation of gas and therefore gives no external indication of spoilage. The product has a sour taste and may or may not have a sour odor when the can is opened.

Hydrogen swell.—A can with swelled ends caused by the formation in the can of hydrogen gas as a result of corrosion of tin plate. Varying quantities of metal are usually dissolved in such cans. The contents are almost always sterile and often fit for food. Such swells are externally indistinguishable from swells caused by micro-biological action, and can only be identified by analysis of the gas in the head-space, and through the heavily etched interior of the container.

Buckles.—A type of swelled can which may be the result of improper cooling. The internal pressure during processing may be so great as to bulge or distort the can ends so that they cannot return to their normal position after cooling. The seams of such cans are usually strained so badly that they subsequently leak and the cans spoil through the entrance of micro-organisms. A buckled can may also represent the final stage of a swell.

Leakers.—These are cans exuding a portion of the contents. Cans may become leakers through (1) faulty seaming, either by the can maker or canner (usually the latter); (2) defective tin plate; (3) internal corrosion or external rusting; (4) buckling; (5) excessive pressure within the can as a result of gas formation caused by micro-biological action in decomposition, or by hydrogen gas through corrosion; (6) external damage such as battering, caused by excessively rough handling in manufacture or shipping; (7) nail holes occurring when cases are poorly or carelessly nailed or are damaged in shipment.

Paneled cans.—These are cans ruptured or distorted through excessive external pressure; that is, they are the opposite of buckles.

PHYSICAL AND CHEMICAL DETERIORATION

The most important factors in deterioration, loss, or spoilage brought about through physical or chemical means are: (1) Discoloration, (2) perforation and corrosion of tin plate; (3) foreign tastes; (4) undesirable textures; (5) freezing; (6) rusting; (7) faulty technique; and (8) unsuitable products.

DISCOLORATION

The problem of discoloration is most serious in packing shellfish and crustacea, but it may also be met with in canning salmon, chowders, fish cakes, kippered herring and other fishery products. It is usually due to physical or chemical action, but may be caused by micro-biological processes, for example, the "angry" or deep-red color sometimes observed near the backbone in tainted canned fish. This color tends to fade on exposure to the air.

BLACKENING

Blackening of the contents or inside of the can is most often encountered in packing crab, clams, shrimp and lobster, but may also be found in other canned products. It occurs most readily where the product has an alkaline reaction. Sulfur compounds in the flesh of these species break down in processing and unite with the iron base of the tin plate to form iron sulfide. This substance is not injurious to the consumer, but the product acquires a most unappetizing appearance and unpleasant flavor.

Formerly, sulfide blackening in canned marine products could only be combated by the use of parchment-paper can liners, preventing contact between food and container, and by the addition of small amounts of organic acid. Studies by the Research Laboratory of the National Canners Association indicated that zinc salts would reduce the formation of black in canned corn by combining with sulfide compounds to form zinc instead of iron sulfide. Zinc sulfide is harmless, white and is therefore unnoticed. This laboratory then developed a lacquer containing small amounts of zinc, to be used as an inside lining for cans used for products liable to blackening. As the zinc is contained in the lacquer and the sulfide formed is also trapped there, little or no zinc is found in the product. Difficulty in packing vegetables was the primary incentive for this research, but the enamel developed has done more than anything else to reduce or inhibit blackening in canned fishery products. Parchment paper linings and the use of organic acids are still necessary to some extent as blackening may otherwise occur at the side seam, where the enamel lining is occasionally fractured in can making.

COPPER SULFIDE DISCOLORATION

Some discoloration in fish and clam chowders has been traced to the use of copper lined can-filling machines. A thin film of copper oxide or copper salts gradually forms on the copper surface. The chowder coming in contact with the copper dissolves some of these copper salts which then react with sulfides formed in processing, resulting in copper sulfide and causing serious darkening throughout the product.

A dark, inky blackening may occur in canned clam products when the dark "stomach" or body mass is not removed in canning. The exact nature of this discoloration is not well understood. It is not invariably found in uncleaned canned clams, but appears irregularly and seems to be associated with the type of food material consumed. The only remedy known at present is thorough cleaning and washing of the clams previous to canning.

Some blackening of canned products has been traced to the use of rubber conveyor belts. There is a certain amount of sulfur on the surface of new rubber belts, which may be converted to sulfurous acid by water and heat, then into tin or iron sulfide by union with the metal of the can.

DISCOLORATION CAUSED BY PROCESSING TIMES AND TEMPERATURES

Processing temperatures and pressures may be a cause of discoloration. For instance, minced razor clams processed at 240° F. (10-lb. pressure) are appreciably darker in color than those processed at 236° F. (8-lb. pressure). Crab processed at 240° F. will acquire an unpleasantly dark color, while the color will not be affected if a longer process at lower temperature is used. Norwegian style fish balls lose their white color if processed over too long a period or at temperatures higher than 228° F. (5-lb. pressure). Packers of these products and others of similar type must control processing times and pressure very closely to prevent serious loss through discoloration. The use of processes at 10 pounds or higher pressure, considered necessary in packing most non-acid products, must be foregone if a merchantable product is to be secured. While processes used for clams, crabs and fish balls are of the "border line" type, loss through insufficient sterilization is generally slight.

STACK BURNING

This type of discoloration is similar to that caused by overprocessing; in fact, it is a form of over processing. A considerable amount of heat is retained over a long period when canned products are stacked or cased before they are sufficiently cooled. Cooking goes on over a much longer period than is intended, which affects both color and flavor unfavorably. Stack burning is usually thought of in connection with the canning of fruits, or possibly such marine products as clams or lobster. Nevertheless Clough (1937) points out instances of deterioration through stack burning in canned salmon and warns that discoloration through this cause must be guarded against in canneries with a large daily production, where it is a temptation to warehouse the pack at the earliest possible moment.

PERFORATION AND CORROSION

Loss in canning may occur through perforation, the product "eating" through the wall of the container, or the inside may become corroded or etched so that the product is unmerchantable.

Loss is usually greatest in the canning of acid fruits, but may occur in the canning of fishery products though more rarely.

Corrosion depends to a large degree on the presence of oxygen. Cruess (1938) reported that in the presence of oxygen the can acts as a primary cell of the oxidation type. That is, the reactions which occur in the can may be explained upon the basis of an electrolysis in which oxides of tin and iron are formed and hydrogen is liberated.

Slack-filled cans are therefore more liable to corrosion than well filled cans of the same product held under the same conditions, for the headspace is greater and the volume of air contained is larger. Other things being equal, cans with low vacuum are more liable to corrosion than containers with a high vacuum. Air should be expelled from product and headspace as completely as possible.

The rate of corrosion and perforation in tin cans, like other chemical reactions, is dependent on the temperature; that is, it increases in rapidity as the temperature of storage is raised. For this reason it is advisable to store canned goods in a cool place, thus minimizing perforation by reducing the rate of corrosion.

Increased corrosion as well as stack burning may be the result of packing the cans while still warm or stacking them in large piles while insufficiently cooled. Cans should be thoroughly cooled before packing or stacking to reduce corrosion as well as for reasons given elsewhere.

FOREIGN TASTES

Canned fishery products have been ruined through such causes as lubricating oil dripping into the cans while passing through filling or sealing machines. Lack of sanitation in canning is apt to cause foreign tastes, as in poor cleansing of brine tanks or pipe lines leading to fillers in products such as soups or chowders. Foreign tastes may also be due to the presence of micro–organisms. Canned salmon is believed to have acquired disagreeable flavors because the salmon had consumed certain odoriferous plankton such as pteropods.[21] Insufficiently cleaned raw products such as clams may cause "foreign tastes" in the canned products.

UNDESIRABLE TEXTURES

In some areas hardness of the water used in canning may give the product an undesirable texture. Calcium salts are absorbed from such water, toughening the product. This defect is most apt to occur in vegetable and fruit canning, but is also possible, theoretically at least, in the canning of fishery products.

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[21] McMillin, Harvey. Abnormal odors in salmon. Bull. National Canners Association, Northwest Branch. 3 pp. Seattle.

Important instances of undesirable texture occur where fish are brined or salted previous to canning. If the degree of salting is at all excessive, the texture becomes fibrous and stringy after processing, in addition to being much too salty in flavor. Some fish such as albacore are canned after being frozen. If the fish are not properly frozen or are thawed out carelessly, the texture of the flesh is impaired. This is evidenced by perforations which are the result of the formation of large ice crystals in the flesh. These are quite distinct from the "honeycombing" sometimes found in the canning of stale products.

FREEZING

Storage of canned foods at too low a temperature is just as injurious as at too high a temperature. Much loss is caused by the freezing of canned goods. Data on loss through freezing are not extensive, but it is believed that some canned foods, including salmon and tuna, are not affected. The amount of damage is usually greater when the products are thawed rapidly.

Condensation of moisture may occur, resulting in the formation of drops of water on the exterior of the containers, if there is too great a difference between the temperature of the frozen product and the room in which it is held. This may cause rusting of the cans or spotting of the labels, even if no greater damage is done. For this reason canned products should be thawed slowly at a temperature only slightly above 32° F.

In some products there may be a separation of liquid, causing a watery appearance. Freezing progresses from the outside of the can toward the center and forces out of solution and concentrates near the center of the can, the salts and other soluble constituents. The separated materials may not again regain their uniform distribution on thawing.

RUSTING

Cans may rust both internally and externally. Rusting is a form of corrosion, but must be considered separately as the formation is influenced by factors of special importance and it is the most common yet most easily corrected type. Rust is formed through combination of iron with oxygen in the presence of moisture, the rate of formation being influenced by temperature and also by acidity or pH. The latter is rarely, if ever, a factor in internal rusting in canned fishery products.

Internal rust may be formed during storage of the empty container, especially along the side seam. If conditions after packing are favorable, the presence of small flecks of rust may accelerate rusting. Rust may also be formed after packing. In this instance it is usually due to oxygen in the headspace, as the result of improper, that is, slack fill, with excessive headspace, and to insufficient exhaust. In some products such as oily fish like salmon, tuna or sardines, where the oxygen is absorbed by the product, there is little danger of internal rusting but in non-oily products, with considerable liquid, such as fish roe and clams, this possibility must be kept in mind.

External rusting is largely caused by poor storage and to a lesser extent by faulty packing methods. There should be no opening in a storage warehouse through which rain, snow or other atmospheric moisture may enter. Floor areas are apt to be moist in buildings of ordinary construction which may be otherwise dry. If cases are resting directly on such a floor the moisture gradually seeps through the case bottoms and may eventually rust the bottom layers of cans. The most common cause of rusting during storage is believed to be due to sweating. Sweating is most apt to occur if the temperature of the warehouse is high in contrast to the temperature of the product, or if the relative humidity of the atmosphere is high, and if there is excessive variation in temperature and lack of ventilation. Three rules should be observed to prevent rusting during storage:

1. The warehouse should be dry and well constructed.
2. The temperature should be uniform.
3. The warehouse should be well ventilated.

External rusting may also be caused by faulty packing procedures such as:

1. Processing in retorts:
    a. Improperly vented.
    b. Using a long coming-up time.
    c. Using low pressure steam containing considerable moisture.
2. Water cooling:
    a. To temperatures below 100° F., when residual surface moisture will not evaporate.
    b. Failure to remove surface water on cans after cooling mechanically.
3. Casing:
    a. In wooden boxes made from green lumber.
    b. In wooden cases which have become damp.
4. Chemical composition of water used in processing and cooling.
5. Label pastes. Instances have occurred where rusting was traced to label pastes with high hygroscopic (moisture absorbing) properties.

FAULTY TECHNIQUE

Faulty technique is due to ignorance, carelessness and dependance on outdated or obsolete methods or equipment. Most of these factors have been mentioned incidentally in the discussion of physical and chemical factors in deterioration, but poor technique must also be considered a direct as well as a contributory cause of deterioration.

Ignorance may be corrected if the packer is willing to study the principles on which canning is based, rather than place dependance on the tedious and expensive trial and error method which often leads to false conclusions. Information on canning technique is available to the industry through the efforts of the National Canners Association, the research departments of the can and canning machinery manufacturers, trade journals and governmental agencies.

Carelessness may be combated only by vigilance on the part of the packer, who must insist on exactness in methods and penalize any infraction of rules. Dependance on outdated methods is itself a type of ignorance. Certainly a man who, having once learned the trade, refuses to study, cannot be called intelligent. Dependance on obsolete equipment is poor economy. Such equipment is apt to be defective resulting in higher packing costs and lower quality.

Faulty technique includes such factors as slack and overfill, insufficient exhaust of vacuum, excessive cook, insufficient cooling, and other factors too numerous to list. Strictly speaking, poor workmanship in packing, such as cross fill in salmon canning, visceral material in canned roe, or bits of shell and antennae in canned shrimp, cannot be included as this discussion is concerned with changes occurring after processing.

UNSUITABLE PRODUCTS

Because of changes taking place in canning, due to the structure or composition of the flesh, certain species of fish are not suitable for canning by any known method. Grayfish (dogfish) is appetizing and edible if used fresh, although the flesh contains urea. In processing, the urea is transformed into ammonia making the flesh inedible. During the World War grayfish were canned as a food conservation measure, but the pack was a total loss.

Seafood cocktails are packed in glass and are hermetically sealed without sterilization. Attempts to lengthen the period of preservation by processing have thus far failed, since the degree of heat necessary to process the seafood portion of the ingredients causes caramelization of the sauce, with consequent darkening in color and "burnt" flavor. Products such as bismarck herring or rollmops are prepared from salt herring or are salted in preparation. Processing these articles causes the texture to become tough and fibrous. Other instances may occur to the reader in his own experience.

SPOILAGE BY MICRO-ORGANISMS

Spoilage through micro-biological action may occur before or after canning. Spoilage before canning is dealt with at length in the discussions on raw material and sterilization. This discussion is concerned only with changes caused by micro-organisms *after* processing. Spoilage after canning may be caused by organisms of low or high heat resistance.

Spoilage by organisms of low heat resistance is due in most instances to leaky or improperly closed cans. Deterioration in these instances is primarily due to physical and chemical causes and bacterial spoilage is secondary, occurring only because these changes have already taken place. If living organisms of low heat resistance are found, the containers should be carefully examined for defects. Processes now in use are sufficient to destroy any organisms of this group. The organisms of low heat resistance in canned seafoods are predominantly of the cocci type.

The bacterial flora of canneries packing marine products have been carefully studied by Lang (1935), who concluded that micro-organisms in marine products canneries are largely of the cocci group and states that it is also apparent that they are readily destroyed by heat, and that the cleaning up of the premises after the butchering operation may be made sufficiently effective to prevent their dissemination to other departments of the packing plant. Assuming that these deductions are correct, it may be concluded that the presence of cocci is a more important factor in the preservation of the raw product after catching, in transit, and prior to precooking than it is in the canning and sterilization procedures.

Bacterial spoilage in canned fish and shellfish is caused almost entirely by organisms of high heat resistance, and may be divided into two general types, gaseous and non-gaseous.

GASEOUS SPOILAGE

Swelled or "bulging" can ends are a common indication of gaseous decomposition. The ends of the can may be pushed out by other causes but this cannot be determined by external examination. Any container with swelled ends should be regarded as unmerchantable.

The gas-forming organisms found in canned fishery products are almost always spore-formers of the anaerobic or facultative anaerobic types. Organisms found quite commonly are *Clostridium welchii* and *Clostridium sporogenes.* Gas formation is accompanied by an extremely foul and offensive odor. Cans of clams cultured with sporogenes and insufficiently processed became swells in from 10 to 90 days. The contents were almost entirely liquefied and discolored to an inky black hue (Jarvis and Puncochar, 1940).

Another gas-forming heat-resistant organism is *Clostridium botulinum.* Spoilage may not always be accompanied by the excessively disagreeable odor, but the product will have lost its normal odor and may have an "off" smell difficult to describe. *Clostridium botulinum* has been isolated from home canned fishery products within the last few years but it has not been found in any commercially canned fishery product since 1925. The toxin produced by this organism is a causative agent of food poisoning. In studying the bacterial flora of marine products Lang found evidence of the presence of gas-producing anaerobic thermophiles on fish carts and in slime previous to canning, but no gas producing thermophiles were isolated from among organisms found present after processing.

The resistance of these organisms varies. Some resist boiling for 4 and others for 12 hours. Certain organisms are destroyed by exposure of 110° C. (230° F.) for 10 minutes while others withstand 120° C. (240° F.) for 10 minutes. Heat processes in canning must be determined on the basis of maximum heat resistance in order to secure commercial sterility and eliminate the possibility of spoilage by putrefactive gas-producing organisms.

NON-GASEOUS SPOILAGE

There is no external indication of non-gaseous spoilage. The ends of the containers are flat and the contents may be normal in appearance. An "off" odor may or may not be noticeable, but the product is sour in taste. This type of spoilage is known as "flat souring." It has been studied most extensively in relation to the canning of vegetables, but also occurs in canned fish and seafoods. Fellers (1927) found spoilage of this type in chinook, coho and pink salmon; in crab, and in shrimp. It has also been found in clams and fish roe and its presence is possible in other seafoods.

Some of the organisms causing flat souring are aerobic spore formers such as *Bacillus cereus, B. mesentericus* and *B. vulgatus.* While flat souring has been most common in cans with a low vacuum, it has been noted in cans with vacuums of 8 to 10 inches.

It is believed that flat souring by aerobic spore formers is due to a heavily increased contamination of the raw material, insufficient process, or a combination of both. Fellers questions the theory that high vacuum is effective in preventing spoilage in certain marine products, and studies made during the past few years tend to confirm his belief.

It is also suggested that souring may occur previous to processing, especially in plants packing clams, crabs, oysters and shrimp. The rate of operation is often slow and trays of material may stand an hour or more before being filled into the cans. When operating at a slow rate, 45 minutes or more are required to fill three standard retort baskets. Where the partially filled retort baskets are also allowed to stand over the noon hour without being processed, the time may be much longer, sufficient for souring to develop, especially on hot days. Subsequent sterilization prevents decomposition but cannot remove any souring which has occurred.

While flat souring may be caused by aerobic spore formers if conditions are favorable, much of the flat souring in canned fishery products is due to the action of thermophilic micro-organisms which develop only at temperatures higher than those at which these products are normally held. Cans of salmon or other seafoods may be piled in large stacks while the cans are still warm, and left for several days. Cooling is delayed to such an extent that the contents remain at a temperature favorable to the growth of thermophilic organisms, long enough for spoilage to develop. Vegetable canners have long been warned against this practice, but its importance has not been recognized as a spoilage factor in canning marine products.

Storage temperature is also important. Thermophilic spoilage may develop in canned fishery products held in warm storerooms, while it would not have appeared if the temperature had not been unusually high. For example, canned fishery products may be placed in attic storerooms under a sheet iron roof, where the temperature may reach 100° F. or more in summer. Such temperatures are favorable to the development of thermophilic organisms as well as being a causative agent of chemical and physical deterioration. Storage at temperatures between 40 and 50° F. will greatly reduce the possibility of flat souring by thermophiles and deterioration of texture, such as softening. High storage temperatures are encountered most often during summer weather in inland regions and among retailers or small distributors. The packer may be unable to control storage conditions, except as he is able to educate jobber and retailer on the importance of proper handling in maintaining quality.

EXAMINATION OF CANNED FISHERY PRODUCTS

Laboratory examination of canned fishery products is made for two purposes, for the enforcement of food and drug regulations and for control purposes to enable the manufacturer to improve the quality, or as a means of determining the quality when the manufacturer is disposing of his pack.

The U. S. Food and Drug official uses much the same methods as the trade examiner to determine whether a canned product is good and wholesome, but if spoilage or inferior quality is indicated in addition, chemical analyses with elaborate and complicated analytical techniques are sometimes required. Chemical analyses are necessary in legal proceedings as the evidence must be sufficiently strong to convince the court that the canned food is not good and wholesome. Methods of analysis which are recognized in court are found in the manual of the Association of Official Agricultural Chemists (1940). In addition, food and drug officials and manufacturers' chemists may offer evidence based on analytical methods from other sources.

In most instances the food technologist in making examinations for control purposes does not require an elaborate analytical technique. He makes use of a few simple tests and depends principally on accurate observation and keenness of the physical senses.

The advantages of an adequate system of grading have been acknowledged from time to time, but little progress has been made in the establishment of grades. With a few exceptions, at the present time, grade depends on species and canning area or is based on the reputation of a brand, rather than on established quality factors. Methods of examination may vary between laboratories and the criteria of the individual examiner may vary from time to time. Published information of value is limited. Only in the case of salmon has a determined effort been made to work out a systematic practical method for the examination of a canned fishery product. The results of the study of the Northwest Branch, National Canners Association, on the examination of canned salmon should be carefully studied by all canning technologists (Clark, *et al.*, 1923).

DESCRIPTION OF LOT

A systematic method for the examination of any canned fishery product begins with a description of the particular lot to be examined. Descriptive data must be very complete and should include the number of cases, size of the container, code mark, variety of product, brand or label and the location of the parcel. The place where the parcel is stored should be noted for several reasons, of which the most important is that the quality of the product may be affected by conditions of storage. The packer, cannery, date packed and any other points that may aid in identifying that particular lot should also be noted. It is suggested that a label from one of the sample cans be attached to the record sheet for reference in questions arising after disposition of the sample.

Coding has been developed to the extent that it is possible to determine even the retort load in which the cans were processed. However, a great deal of improvement is needed in the coding of fishery products. Some products are only coded to give the packer and season when packed, while other products are not coded at all. An accurately coded product not only simplifies the work of the food examiner, but enables him to furnish more accurate and detailed information to the packer.

SAMPLING

Many packers, when requesting laboratory examination of their product, send in samples of half a dozen cans or less, usually taken in a very haphazard manner. Several codes or portions of the pack may be included in a single parcel. Even where only a single code or portion of the pack is concerned such samples are too small to be representative and any examination will probably be inaccurate. Where the pack is uncoded or the codes not segregated, a single case may include cans from more than one lot. Under such circumstances the removal of a few cans from a single case does not constitute a representative sample and the probabilities are against securing accurate data.

Sampling is only possible on a systematic and representative basis, when the pack is coded and the sample is sufficiently large in size. Under such conditions sampling is simplified, the sample furnishes valuable data for control of packing methods, and can be considered as truly representative of the quality of the pack.

In the examination of salmon, Clark, *et al.* (1923) stated that all that can be done with uncoded packs is to attempt to get a representative sample by taking one or two cans from each of a considerable number of cases situated in all parts of the parcel. Ninety-six cans are usually drawn in this manner in parcels of 1,000 cases, and an increasingly smaller proportion from increasingly larger parcels.

A sample of any fishery product should consist of at least 24 cans, if the lot is less than 1,000 cases. If the pack is new to the examiner or if it is questionable, a larger number of cans is required. One half of the sample should be set aside for reference, while the remainder is examined. If the results of the examination are questioned, authentic samples are then available for use in any controversy, or as evidence in case of legal action. If the cans are found to be uniformly good in quality, the unopened portion of the sample may be returned to the packer if not needed.

When the sample is taken, the cases opened should be inspected and the external condition of the cans noted, especially the condition of the enameled ends, cleanness of the cans, condition of the labels, and the presence of swelled, leaky, rusted and dented or battered cans. While the percentage of defective or damaged containers should be determined, no can which is obviously abnormal should be included in a sample taken for examination.

A sample should not be examined immediately after it is drawn from the pack, but should be held in the examining laboratory until it has reached room temperature, preferably about 65° F., or for a period of about 48 hours. Samples examined immediately after removal from the warehouse may give misleading results. If they have been stored at very warm or cold temperatures, the significance of the vacuum obtained is difficult to interpret accurately. If the contents remain at a low temperature, it is more difficult to detect abnormal ("off") odors, or odors of decomposition.

BACTERIOLOGICAL EXAMINATION

A bacteriological or microscopic examination of a canned fishery or other food product is made to determine the number and types of any organisms present, to confirm data in heat penetration tests, to determine the quality of raw material used, the quality of the pack, or the cause of spoilage, if present. The number of samples examined bacteriologically will vary with the type of pack and character of information desired, but should not be less than 12 cans as a minimum and a sample of 24 cans is preferable. Data obtained as a result of bacteriological examination may be misinterpreted unless correlated with the results of a careful physical examination and is of the fullest value if processing data are also available.

Samples intended for bacteriological examination should be first incubated for at least a week at a temperature of 55° C. (131° F.), as thermophilic organisms develop only at high temperatures and physical changes are also hastened under such conditions. When possible, bacteriological examinations should be conducted in a room separated from the rest of the laboratory, to reduce the possibility of contamination.

PREPARING THE SAMPLE

The tops of the cans should first be washed thoroughly with soap and water, then dried. The top of the can is usually sterilized by flaming with a Bunsen burner, though it may also be done by pouring a small amount of alcohol on the can, and igniting.

When the top is sufficiently cool, the vacuum reading is taken, disinfecting the tip and rubber stopper of the vacuum gauge by dipping it in formalin. The can may then be opened with a sterile can opener flamed in a Bunsen burner each time used, or by punching a hole one-half inch in diameter using a screw driver or brad awl. The can top should be flamed again as an added precaution against contamination. If the container is abnormal, that is, a swell, a sterile towel should be wrapped around the tip of the punch when making the hole to prevent any of the liquid contents from spurting into the room.

TAKING THE SAMPLE

If the contents include considerable liquid the sample may be drawn out through a straight piece of glass tubing, sterilized before use. Tubing is preferable to pipettes as it is more easily cleaned, is not blocked as readily and a more representative sample may be obtained. A sample of approximately 1 cc. of liquid and small particles of solids is required for each inoculation. If there is not sufficient free liquid, a cut is made into the center of the contents with a sterile scalpel and a portion of about 1 gram is removed with sterile forceps for each inoculation. Aerobic and anaerobic plates and tubes should be inoculated for each container. Special media are not required in most cases. Dextrose agar and peptone broth are usually satisfactory culture media. As a rule plates and tubes are incubated 72 hours at 86° F. (30° C.) before being examined. If results are negative, an additional incubation of 48 hours at 131° F. (55° C.) may be given to confirm the negative results and test the presence of thermophilic, heat-resistant organisms, or two sets of cultures may be taken, one incubated at each temperature.

DIRECT MICROSCOPIC EXAMINATION

Microscopic examinations are made by removing a drop of liquid from the can with a sterile loop and placing it in a hanging drop or by preparing and staining a smear on a slide.

Clark, *et al.* (1923), describing the microscopic examination of canned salmon, a type of examination equally applicable to all canned fishery products, stated " * * * that direct microscopic examination of the liquor * * * is sometimes of value, in that often one may determine at once without waiting for the results of the bacteriological tests, whether active spoilage is present. It is also of value in confirming results of the physical and chemical examinations, because in canned decomposed salmon, even when properly processed, large numbers of dead bacteria may be found by use of the microscope. Canned fresh salmon shows few or no dead bacteria by this method. By the use of the microscope, certain parasites and pathological conditions may also be studied."

The results of microscopic examination are then interpreted in the light of available details of the process of manufacture and in correlation with data secured from physical and chemical examination. It should be possible to determine (1) whether further spoilage will occur, (2) whether bacteria gained entrance through defective seams or leaks, and (3) whether bacteria resisted the processing temperature. Inactive or dormant spore forms are not of great significance, as they do not develop due to unfavorable conditions. Bacteria common to the dust and soil, if present, probably come from dust in the empty can. The most common causes of non-sterility are believed to be poor seaming by the canner and under-processing.

PHYSICAL AND ORGANOLEPTIC EXAMINATION

Factors included under a physical and organoleptic examination may be separated into three groups: (1) Quality of the raw material when caught; (2) quality of the raw material when canned; and (3) workmanship in packing.

QUALITY WHEN CAUGHT

The quality of raw material when caught is not uniform for any species. Variation is best illustrated, and has been most thoroughly studied in salmon canning, but is found in other products. Salmon for canning are caught only during the spawning migration. Once started on the journey, they no longer feed, but depend on stored-up body fat for nourishment. "Therefore, the amount of this fat within their bodies gradually decreases, and fish which are caught late in their migration period are poorer in quality and lower in food value. Not only does the amount of fat decrease, but the color of the flesh fades out and the canned product has a poorer color. In general, salmon packed early in the canning season are of better quality than those packed later" (Clark, *et al.*, 1923).

In some products size is important in determining the quality when caught. Maine sardines are considered of higher quality if small, shrimp if they are large. Size may vary with the locality and time in the season when caught. It is also affected by the density of population on a fishing ground and amount of food present in the water, which may vary with the season in any given area. Degree of temperature and change in salinity may affect size ranges, as with oysters.

Color of the flesh is important for canned salmon, shrimp and crab. In fact, a characteristic color has been established for these species. Color is noted in the examination of other canned fishery products, but in them the color is a factor in workmanship in packing or in determining the quality when canned.

The amount of free liquid and oil may be used as an indicator of quality in such species as salmon, shad, alewife or river herring and mackerel. The average amount of oil and liquid per can has been carefully worked out for each species of salmon. In living fish the amount of water in the flesh tends to increase as the fat content decreases. If the amount of liquid is much higher than is usual, the amount of free oil is low, indicating low quality fish. This factor is not significant in products such as "wet-pack" shrimp and oysters packed in brine.

QUALITY WHEN CANNED

Fish and shellfish are more delicate in structure than other flesh foods, are readily injured and decompose rapidly. A fish may be of good quality when caught but poor when canned. The original quality may have been destroyed by the method or conditions of handling the catch, as described in the discussion of handling and transportation. Examiners for the enforcement of U. S. Food and Drug Administration regulations are especially interested in the condition of the fish when canned, *as the law stresses fitness for food, rather than standards or grades of quality.*

The factors used in determining quality when canned are odor, texture, reddening of the flesh, "honeycombing" and turbidity of liquid.

ODOR

Odor is the most important and most reliable indication of decomposition in the examination of canned fishery products, and is usually the factor which decides whether a can of fish shall be considered as fit for food. In determining the odor a great deal depends on the keenness of this sense in the examiner. Some persons have an abnormally sensitive sense of smell particularly those with a "weak stomach." Others have a deficient sense of smell. The sense of smell also may be affected by the use of liquor, or by smoking just before an examination.

In smelling salmon or other fish a handful of the contents of the can is broken between the hands, immediately after which it is opened up and held close under the nose. Odor may be classified as good, stale, tainted and putrid. Fishery products canned when fresh have a normal "marine" odor, not at all unpleasant or disagreeable. The odor may be lacking, but unless there is a definite odor of staleness, the classification should be "good."

If stale fish are canned, there is a definitely abnormal odor, which is best described as a slight odor of decomposition. The odor disappears after the contents have been broken up and exposed to the air for a few minutes. Such a product may be considered to be of poor quality, yet not unfit for food.

Fish canned when tainted, that is, after decomposition has definitely set in, will give off an unmistakable odor of decomposition which does not disappear after the cans have been opened and allowed to stand for a few minutes. The examiner lists such an odor as "tainted" and the product is regarded as unsalable, although it may not be actually harmful if eaten.

The classification of "putrid" is reserved for an extreme degree of decomposition. In some cases the odor is persistent and disagreeable, noticeable even at a distance as soon as the can is opened and by a person unacquainted with the examination of canned foods. Such cans, of course, are unmerchantable and the contents are inedible. Shellfish canned when spoiled, have the most offensive odor of putridity and if this odor is found in a sample of canned clams, for example, it will appear in almost every can, making a detailed examination impossible and unnecessary.

Some odors may be encountered which, while perhaps abnormal, are not odors of decomposition, and should not be considered as indications of spoilage. Canned crustaceans, such as "dry pack" shrimp, crab and lobster may give off a slight ammoniacal odor, which is probably due to degree of process and does not affect the quality or fitness for food. Sometimes a "musty" or "muddy" odor is detected, usually in fish taken in fresh water, which are soft fleshed and have not been given a pre-treatment to improve the texture. Clams may have a "seaweed" odor, but are perfectly edible, though the appetite appeal may be lessened.

Canned salmon sometimes has a "weedy" or "grassy" odor, which is usually associated with strongly "water-marked" fish. Fish which are caught with hook and line in salt water usually contain partially digested food and often have a characteristic odor not in any way due to decomposition of the flesh. Sometimes a "scorched" or "caramelized" odor is noted which may be due to over-cooking. Canned smoked fish have a "caramelized" or "creosote" odor if smoked too heavily before canning.

TEXTURE

The texture of the flesh may be used as an indicator in some products, but there is such variation that it must be used with caution and only in conjunction with other factors. Softening of texture usually accompanies and corresponds roughly in amount to the degree of decomposition as judged by the odor. It should also be remembered that fat fish will be softer than thin fish of the same species. The portion of the body may make a difference in texture, as for instance, belly flesh may be softer because it is more oily than other sections of the body. Excessive handling of the cans before examination may also adversely affect the texture.

REDDENING OF THE FLESH

Reddening of the flesh is especially important as an indicator of spoilage in the examination of canned salmon but may be used with other products. According to Clark, *et al.* (1923) "The flesh of raw salmon if not promptly canned takes on an unnatural bright red appearance and this color persists through the processing; but when the can is opened this unnatural or so-called 'feverish' red color quickly fades and can usually be distinguished from the true color of the fish. Furthermore, this unnatural reddening is unevenly distributed and most likely to be observed at the tips near the gills, next in the belly walls, and least of all in the back flesh."

Reddening of this type may also be observed in white fleshed fish such as canned herring or sardines, especially along the belly cavity. Reddening in canned roe may be due to poor washing, but roe packed when sour also shows a definite "bloody" color, evenly distributed throughout the mass.

HONEYCOMBING

Occasionally in packs where the contents of a can consist of two or three pieces solidly packed, it will be noticed that the flakes of flesh are perforated by small holes. The accepted theory accounting for this condition is as follows: When more or less decomposed fish is canned, there is a considerable production of gas in the flesh caused by the growth activity of gas forming bacteria. When such fish are processed, the gas expands and makes little pockets in the flesh. On cooling, the pockets remain and the flesh seems to be filled with small holes or air spaces. This appearance is called "honeycombing," and was originally found in canned salmon but may occur in other products such as tuna and sardines. If a small piece of "honeycombed" flesh is placed on the tip of the tongue and held there for a short time, a sharp biting taste is sensed, a flavor like that of "sharp" or "old" cheese. This test is not recommended if the can is obviously spoiled.

TURBIDITY OF LIQUID

The degree of turbidity or color of liquid is sometimes used as a factor in determining condition when canned. For instance, in canned oysters a grey liquid is considered a sign of old or inferior oysters. If the product is packed when fresh, the free liquid extracted in processing or the added brine is fairly clear. The degree of turbidity tends to increase with advance in decomposition. However, the liquid may also be turbid if the product has been handled roughly, is examined at a very low temperature or has been stored at a high temperature. Turbidity is useful as a corroborative index of spoilage but should not be considered apart from other evidence.

WORKMANSHIP IN PACKING

Workmanship in packing is an important factor in establishing the quality of the canned product and under this head are included all those canning operations, the effects of which may be observed in the canned product.

EXTERNAL APPEARANCE

Examination for workmanship begins with a determination of the external appearance of the container and is usually made in sampling or as the first stage in laboratory examination. If there are rust spots, the sides are dull and dirty, the enameled ends are scratched or show "peeled" spots, or if the cans are dented or battered, then the external condition of the container does not show good workmanship in packing. Labels should be fresh, clean and properly placed on the cans. Defective labels should not be used, nor should they be torn or scratched. The product may be of fancy grade, but if through carelessness or inattention it reaches the grocer's shelf with the faults listed above, the appearance will not favorably attract the consumer.

VACUUM

Vacuum is determined just before bacteriological samples are taken or the cans are opened. A gauge equipped with a hollow piercing point surrounded by a soft rubber gasket is pressed down into the lid, giving a reading indicating the amount of vacuum in inches. A vacuum of 7 inches or more is generally regarded as satisfactory, but it should average 9 to 12 inches to be classed as good. An average vacuum meeting this standard is not satisfactory if any considerable number of cans in the sample show an extremely low or no vacuum, though there may be no signs of internal pressure. Any appreciable percentage of low vacuum cans indicates defective seaming in the cannery, poor vacuumizing, overfilling or similar mechanical defects.

HEADSPACE

The cans are opened by any cutter which will remove the entire end, either just within the top seam or cutting around the side just below. Headspace is measured from the top of the contents to the bottom of the lid and is recorded in fractions of an inch, usually sixteenths. The amount of headspace necessary for good canning practice varies to some extent with size of container, especially when products are packed in the larger sizes of cans. For the great bulk of fishery products, 3/16 inch may be considered satisfactory. If the variations are too wide, the amount of headspace is an indication of over or under filling.

Checking the headspace is especially important since the amendment of July 8, 1930 (also known as the McNary-Mapes Act) was added to the Food and Drug Act. Under this Act, it has been ruled that if the headspace forms 1/10 or more the height of the can, the product is slack filled and sub-standard, even though the declaration of weight on the label is correct. This requirement is included in the new Food, Drug and Cosmetic Act (Act of June 25, 1938; 52 Stat. 1040; 21 U. S. C. 301-392).

AMOUNT OF LIQUID

When the headspace has been determined, the drained weight may be taken, if necessary, after which the contents of the cans are emptied into dishes. Shallow white enamel pans are very satisfactory for this purpose. The amount of liquid is measured by pouring into glass cylinders, graduated in cubic centimeters. In products where turbidity determinations are made on individual containers, a 100 cc. cylinder is used, but when, as in the examination of salmon, free liquid and oil are judged on the basis of a dozen containers, a 1000 cc. graduate is necessary.

FILL

Fill includes not only the total area of the container taken up by the contents as determined by headspace and net weight, but also *how* the contents are packed. Fill varies with the product, and to some extent, depends on whether the can has been filled in mechanically or by hand. In products such as salmon, shad or tuna, there should not be more than two or three pieces, and the cut ends should be packed facing the can ends with the sides parallel to the sides of the containers. Pieces should not be jammed or crumpled in. Ends should not be ragged and uneven, but cut clean and smooth.

In products such as Maine sardines, the fish should be packed with tails to the center and with sides at an angle, so that only the silver skin shows. In sardines and herring the skin and flesh should not be broken in filling. Fill is judged by the drained weight, amount of liquid and headspace in products such as shrimp and oysters. In products such as chowders, fill is judged by the proportion of the ingredients, that is, has an even mixture been obtained?

As a rule, under proper supervision, hand filled packs show a more attractive appearance. If large herring or mackerel are packed in tall cans, the contents should be removable in an almost solid single cylinder. It is bad filling practice in this type of pack to use small ends to fill the center of the can or spaces caused by the size and shape of the fish. If the fish are properly selected for size, trimmed and filled in carefully, alternating heads and tails, there should be little if any need to use scraps and the fill will be more attractive. An occasional unsatisfactory fill may be disregarded, as a small percentage will be found in the most carefully filled packs, but if such cans occur with any degree of frequency, the fill must be classed as poor.

Consistency of the product is distinguishable from texture in some products, where the degree of consistency is affected by and is an indicator of workmanship in packing. In chowders or soups, for instance, consistency, that is, the amount of liquid or "thickeners," is variable at will. The consistency is poor when the chowder is too thin or if too much thickener has been used. In products such as fish pastes, if the texture is rubbery and the pastes are difficult to spread, the consistency is regarded as unsatisfactory. If canned fish cakes crumble when formed into cakes, consistency is poor.

CLEANING

Cleaning varies to some extent with the type of product. The presence of skin in any amount in fish flakes, fish chowder or fish cakes would be considered poor cleaning, but not in other products. The presence of fins is normal in sardines, but indicates poor cleaning in salmon. As a rule, intestines or other offal should not be found and all clotted blood which is removable should have been washed out. Blood may settle behind the backbone and sometimes fish are bruised before the blood has congealed, leaving a discolored bloody area in the flesh. Such blood clots are not removable and are not considered as evidences of poor cleaning.

The presence of foreign objects in the container or extraneous dirt originating from the empty cans or the salt used in packing should be considered as poor cleaning.

COLOR

Color may be affected by workmanship in packing. Clams given an over process will show discoloration. Improper preparation before canning will adversely affect the color of fish chowder or fish cakes and these products are easily discolored by processing at too high a pressure or for too long a period. "Stack-burning" may be a serious cause of discoloration, if canned fishery products are not promptly cooled. Some discoloration or "off" shades of color may be due to insufficient cleaning or washing.

COOK

Sufficiency of cook or process may be determined accurately only on the basis of heat penetration studies and by the results of bacteriological examination. In some products, especially canned salmon, where the contents include relatively large vertebrae friability of vertebrae is used in this determination. The vertebrae should crumble easily when rubbed between the finger tips, and rib bones should be brittle, snapping off readily without bending. According to Clark, *et al* (1923), there does not seem to be any close relationship between sterility and softness of the bones. Cans containing soft bones have sometimes been found to contain living bacteria, while on the other hand, cans with hard bones are often sterile. Hardness of bone varies with species and size of fish. The gelatinous substance within the vertebrae should be well coagulated and opaque.

SEASONING

Seasoning in the canned product depends on the individual taste and should not be subject to rigid standards. Salt or the various condiments should be added only in an amount to satisfy the average taste. The product should not be flat and insipid but neither should it be too heavily salted. Some products are salted more heavily than others to improve the texture, or in other cases to mask a "muddy" flavor. "Water-marked" salmon for example are salted more heavily than fish not in this condition. Increased salt seems to improve flavor in the more poorly flavored fish. It should also be remembered that salt and condiments, or sauces such as oil, require several months after canning to penetrate the flesh thoroughly. Tuna, salmon or sardines may seem insufficiently salted immediately after canning, yet will be found satisfactory a few months later.

FLAVOR

Flavor, as distinguished from amount of salt, should be observed in some products, especially those containing a variety of ingredients. The salt or other seasoning may be sufficient, yet the combination may not give a pleasing flavor. Clam chowder, fish pastes, soups, fish cakes and most specialty products may be cited as belonging to this category. In simple products which have not undergone an elaborate process of manufacture, a caramelized or overcooked flavor may indicate over-processing. This applies especially to products such as minced razor clams or Norwegian style fish balls where the upper and lower limits of processing are close together.

NET WEIGHT

Each can must be correctly marked as to the net weight of the contents to comply with the requirements of the Food, Drug and Cosmetic Act. The examiner should weigh at least 12 unopened and 3 empty cans, calculating the net weight as an average. It is sometimes desirable to record also the net weight of each container. The net weight requirement is a minimum requirement. The average must at least equal, but may exceed it without violation of the law. It should be remembered that if there is a wide variation in net weight between individual containers of the sample, workmanship is poor, even though the average net weight meets the requirement. As a rule the actual net weight of fishery products is in excess of that declared on the label.

It is also necessary to ascertain the drained weight in the examination of certain products such as clams, oysters and wet pack shrimp to which considerable brine or liquid is added in filling, or which are liable to shrinkage in processing. The method for obtaining drained weight is given in Service and Regulatory Announcement 134, U. S. Food and Drug Administration. In order to secure results which may be checked against data from other sources, the examiner should follow the procedure as it is official and accepted by all laboratories.

CHEMICAL EXAMINATION

Chemical examination of a canned fishery product follows the same general method as the examination of any other protein food. As stated in the introductory paragraphs to this discussion, a chemical analysis is required in the regular examination of canned fishery products almost solely as confirmatory evidence where the question of spoilage is involved. As physical evidence obtained by the senses may be questioned in court, determination of freshness or the presence of decomposition products must be established by exact methods with the minimum possibility of mechanical error.

Several analytical procedures are or have been used to determine decomposition. A great deal of research has been conducted on this subject in the last twenty years, but a generally satisfactory method has not yet been developed. Volatile acid content in canned salmon may be useful as an index of decomposition, but this method has not yet been accepted for the examination of salmon and it is not known whether it can be adapted to the examination of other types of canned fishery products. Electrometric methods to determine the freshness of fish fillets have not yet been adapted for use with canned fishery products. The indol test, long used as the principal indicator of decomposition, is now discarded, as are methods based on the determination of ammonia or various nitrogen fractions.

For detailed procedures in the determination of decomposition, the reader is referred to the standard texts on food examination such as Official Methods of Analysis of the Association of Official Agricultural Chemists, and on the analysis of organic substances such as Leach (1920) and Mitchell (1932).

RECORDS

It is necessary to keep systematic records of examinations for several reasons. In the first place the examiners' work may be readily questioned if this is not done. It is also essential for control purposes, especially in tracing responsibility for certain practices. Improvement of quality requires an immense amount of information on methods in present use. This is accurate and reliable only if detailed records have been kept of the examination of many sample cans of the product, packed at various times in the season, under varying conditions, and from as many locations as possible in the area where the product is canned.

The form used by the technological laboratory of the Fish and Wildlife Service is illustrated on an adjacent page. Where a great deal of control work is done on a single product, a record form should be worked out particularly adapted to that product. Use of a general form such as illustrated might result in the loss of valuable data. The laboratory should first consider its particular needs and the type of information desired before binding itself too closely to a particular form.

Number.................Product.................Brand or label.................

Obtained from.................Place packed.................Code mark.................

Type and size of container.................Number of containers.................

Date examined.................Examined by.................

Container Number		1	2	3	4	5	6	7	8	9	10	11	12
Appearance of container	External Internal												
Vacuum, inches													
Headspace													
Fill	Good Average Poor												
Texture	Firm Sl. soft Soft												
Color	Clear Average Discolored												
Cleaning	Good Average Poor												
Odor	Normal Stale Tainted												
Flavor	Good Average Poor												
Salt	Insufficient Good Excessive												
Liquid (cc.)	Normal Sl. turbid Turbid												
Net weight													
Drained Weight													
Bacteriological: Aerobic plates do tubes													
Anaerobic plates do tubes													
Direct microscopic examination													
Remarks (*)													
Suitability for canning													
General remarks													

(*) Type of organism, etc

CANNERY INSPECTION

Canneries packing fishery products are subject to inspection for regulatory purposes and for the purpose of checking on the methods in use, or to gather information which may enable canners to improve the quality of their pack, correct errors or increase efficiency in methods of production. The latter type is usually voluntary and is organized by trade associations for the benefit of their various members, or it may be a strictly private service operating as a part of the research department of a large canning firm.

Regulatory inspection may be under either State or Federal control. State control may vary from casual inspections by local public health or food and drug officials, to a constant control and check on every lot of canned fishery products processed. Federal control may vary from a general supervision which endeavors to remove adulterated or unfit goods from passing into interstate commerce, but does not set up standards of quality, to an inspection system devised for the supervision of packing individual products such as shrimp, and may control methods of production, packing and processing in individual canneries. Both types of Federal inspection are under jurisdiction of the U. S. Food and Drug Administration, Federal Security Agency. The Fish and Wildlife Service of the U. S. Department of the Interior does not exercise any regulatory powers governing methods of canning fishery products.

TYPES OF INSPECTION

For purpose of illustration, a good example of state cannery inspection is found in California. The canning of fishery products is controlled by state health authorities who prescribe equipment and processing methods. Automatic temperature control and recording devices are required. The pack must be coded and complete records must be kept of each lot canned. No product may be sold until the cannery inspection service is convinced that it is sufficiently processed and complies with all regulations. Packing and processing regulations are based on the result of research studies, data obtained from the packing industry and from the Federal government. Regulations are revised from time to time whenever the need of change is indicated.

Federal inspection has been proposed for several of the more important products, such as salmon or tuna, but to date this system has only been placed in operation in the shrimp canning industry. This inspection service is optional with the individual packer. To obtain it he must make application to the Food and Drug Administration, Washington, D. C., agreeing to comply with regulations prescribing a standard of sanitation for the plant, the equipment required, the processes to be used and sanitary measures to be observed in the canning procedure (Food and Drug Administration, 1938). Inspection is for periods of 6 months, and the packer is charged a fee based on the size of his pack, to pay for the cost of inspection.

Shrimp packed under inspection and certified as complying with the regulations of the Food and Drug Administration bears a legend on the label, "Production supervised by U. S. Food and Drug Administration." Only shrimp so inspected may carry this statement. It is of considerable advantage to a packer to be able to use such a label, as the market tends to consider it as a guarantee of quality. The inspection of shrimp has caused the elimination of undesirable practices in canning and reduced processing difficulties, where it has been put in effect.

In canning salmon, most important of the canned fishery products, dependence is placed on inspection of the pack rather than on inspection of production. The Northwest Branch, National Canners Association, inspects about 90 percent of the salmon packed in the United States and Alaska. Most of this work is performed at its laboratory in Seattle, Washington. This inspection is primarily intended for the detection and elimination of any lots of canned salmon which might be considered unfit for food, but if the packer so desires, a complete organoleptic examination is made, obtaining considerable information on workmanship in packing and similar factors, which has made it possible to improve methods of production and quality.

This Association formerly maintained an inspection service in Alaska. Cannery inspectors visited the plants of member firms, reporting on sanitation and methods of procedure. Methods were made more efficient, sanitation was improved and the quality of the pack was bettered. When these objects were accomplished inspection was abandoned because of cost of operation and difficulties in obtaining trained personnel.

In the Canadian salmon canning industry the pack is not inspected by a trade association or other organization within the industry, but by a governmental agency, the Board of Inspection, operating under the "Meat and Canned Foods Act" of 1907, created by an Order in Council of April 4, 1932, subsequently amended. All salmon canned in Canada must be inspected before it is marketed by the packer. The board is made up of three experienced canned salmon examiners, who make an inspection of each lot packed, reporting on its condition and quality. If the examiners regard it as "fresh, firm, well packed and in good merchantable condition," a certificate to this effect is issued to the packers.

Canned salmon which is determined "to be sound, wholesome, and fit for human food," but which does not fulfill the requirements for a first quality product, is graded as "Second Quality." This legend is embossed on can ends which are clinched on over the original end or ends, so as to conceal the word "Canada" usually embossed thereon (Clough and Clark, 1934). Canned salmon which cannot be included under either of these classes is seized and condemned. If it is not required by the Department of Fisheries for feeding purposes at fish hatcheries, it is destroyed. Additional requirements of the Canadian regulations are that each can must be code marked in such fashion as to indicate the species of salmon, the date of pack and the name of the packer.

ADVANTAGES AND DISADVANTAGES

Inspection at the cannery is regarded as more effective than inspection of the pack at the primary marketing point. The advantages of pack inspection are that it can be handled by a much smaller personnel and the cost of inspection is not as great. The disadvantages of pack inspection are that it is often made too late to change the current pack. Any alterations necessary must be instituted the following season, except that if improper sealing is noted it is possible to telegraph the cannery so that the necessary changes may be made. With pack inspection it is more difficult to pin down the exact cause of defects appearing in the pack or recommend changes necessary for improvement.

The disadvantages of cannery inspection are greater cost of operation and the difficulty of obtaining a properly trained personnel. Such work is apt to be seasonal with a comparatively brief period of employment. Properly qualified men with the necessary technical or practical knowledge do not ordinarily care to accept employment under such conditions, or if they do, must be frequently replaced, which requires the training of new men with a loss of efficiency during the training period.

REQUIREMENTS FOR A CANNERY INSPECTOR

Men hired as fish cannery inspectors should meet certain requirements. They should have training in chemistry and bacteriology. Courses in sanitation and public health are desirable and also education in the fundamental principles of food preservation. Practical experience in the fish canning industry is also very useful. A man with academic training only will acquire a knowledge of methods in time, but as this is gained largely by observation it is never as intimate or accurate as when gained by active participation. Over dependance on observation and on literature dealing with the industry is apt to lead to erroneous conclusions. On the other hand the man who has practical training only may not realize the importance of the fundamental principles of canning. A well balanced combination of practical experience with academic training should give the best results.

The personality of the inspector is as important as his training. He should be tactful and, while insisting on the enforcement of inspection regulations, should avoid an arbitrary attitude. Common sense is a necessary requisite. Lack of this factor is one of the principal causes of antagonism to inspection. For example, a regulation required that the raw material must not come in contact with wood during preparation and packing. A parcel of the *canned* product was packed in wooden shipping containers. The inspector refused to certify the parcel on the grounds that the product was in contact with wood. While his decision was ultimately reversed, the packer was caused loss and annoyance, which might have been avoided with application of common sense.

CONDUCT OF A CANNERY INSPECTION

Regulations issued by the inspection agency making the inspection usually give complete instructions adapted to the situation. To summarize very briefly, inspection begins with the raw material and ends with the shipping of the finished product, and to be effective, must control any factor within this period affecting the quality of the pack.

The cannery inspector should avoid issuing orders directly to the cannery crew whenever possible. If he wishes anything done, a request should be made to the cannery foreman which does not mean that the foreman should be frequently bothered by minor requests. However, the order should be issued by the cannery foreman if it is necessary to take a man from his regular tasks to perform some work in connection with the inspection.

The inspector should have his records up to date at all times and should take care to avoid possible errors. For this reason. records should be checked frequently. If the packer claims error even though the inspector feels him to be at fault, the claim should not be disputed at length but referred to the central inspection authority. Cordial relations should be maintained with the packer, but the inspector should not allow himself to perform duties outside of the field of inspection or fraternize to such an extent that he is forgetful of his obligations to the inspection service.

In a few instances inspectors are selected from among the employees of a cannery, They are paid by the inspection service, which is reimbursed by the packer. Inspections carried out under such conditions are apt to be ineffective. The inspector is too closely identified with the interests of the packer to insist on enforcement of regulations if the packer disobeys, or the plant is so familiar that he is unable to see clearly the errors he is supposed to eliminate. If it is necessary to choose inspectors from among cannery employees, they should not be stationed with the packer from whom they were obtained.

CANNED FISHERY PRODUCTS AS FOOD

While nutritional value is given more consideration than formerly, attractive appearance, palatability, and price are deciding factors in determining the diet of the average consumer. To urge consumption of an article simply and solely because "it is good for you" makes eating that food a duty and not a pleasure. The consumer buys no more than he considers absolutely necessary.

Factors used in the purchase of food are (1) nutritive value, (2) appetite appeal, (3) amount of waste, (4) cost, (5) variety of choice, (6) ease of purchase, and (7) ability to purchase in convenient amounts and packages. The food buyer wants to know how canned fishery products meet these requirements. If the information is not satisfactory, he does not buy. A discussion of these factors in relation to canned fishery products should therefore be of interest and value to the industry, especially as published data are scattered and not readily available. It is the purpose of this discussion to bring the information together in convenient form.

NUTRITIVE VALUE

The principal constituents of any food are: (1) Water, (the amount of water is usually larger than that of any other substance); (2) proteins, which are basically nitrogen compounds, represented by muscle fiber; (3) fats as represented by fish oils; (4) carbohydrates, such as starches and sugars, seldom found in fishery products; and (5) mineral elements.

DETERMINING FOOD VALUE

The "proximate composition" of a food includes the percentages of moisture, protein, fat, carbohydrate, if present, and total ash. Formerly it was thought that knowledge of the proximate composition was all that was necessary to measure the comparative food value. A second index measured the heat value of food in terms of calories per unit of weight. The caloric value is useful to determine the amount of food to be consumed for the performance of different activities. However, the modern knowledge of nutrition shows that the functions of food are to yield energy, to build up the body tissues and to regulate and maintain the body processes. Sherman (1933) has summarized the needs as follows:

1. Enough of the digestible organic food stuffs to supply the needs of the body for energy, usually measured in terms of calories.

2. Enough protein of suitable types to meet all needs for essential amino acids.

3. Adequate amount and proper proportions of the mineral elements or ash constituents of the food.

4. Enough of each of the necessary vitamins. Few foods make so varied and valuable a contribution as fishery products.

PROTEINS

All proteins are complex compounds built up of a number of simple nitrogenous substances called "amino acids," of which about 10 are essential to body maintenance and growth. Meat and fish proteins are designated "complete" proteins since they contain all of the essential amino acids in about the right proportion, while those from vegetable sources are less complete. Fish and other animal proteins should be included in the diet to balance the vegetable proteins, so better use can be made of them.

Lanham and Lemon (1938) found that the proteins of the fishery products which they tested compared very favorably with the protein of round steak and casein in growth-promoting value. Oyster protein was found markedly superior to the others, and apparently the fish which contain 10 percent or more of fat have somewhat more complete proteins than those which contain less fat, although the difference was not great (Fig. 65).

The value of a protein is also measured by its digestibility. The protein of fish is easily and quite completely digested. Experimental data show that the corrected digestibility coefficients for the several proteins of fish and crustacea tested were as high or higher than for beef (Lanham and Lemon, 1938; Lanham, *et al.*, 1940). In summary, canned fishery products should be included in the diet to supply a source of efficient and highly digestible protein. The protein of fish can be substituted weight for weight for meat and dairy products protein to good advantage.

OILS AND FATS

The nutritive value of fish oils depends on composition, energy value, digestibility and vitamin content. The composition of fish fats is about the same as that of animal or vegetable fats except that fish fats are liquid at ordinary temperatures. Also, the fats of fresh fish oxidize and become rancid more readily than animal or vegetable fats. However, the fat of canned fishery products is even less liable to rancidity than fresh meat fats because air is excluded from the can.

Fat is important in the diet to supply energy and a certain minimum is needed for the proper functioning of the body. The energy value of fish fats has been estimated as equal to most animal and vegetable fats and about one-fourth greater than that of butter or margarine. From such evidence as is available, the digestibility of fishery products fats as a class appears to be equal

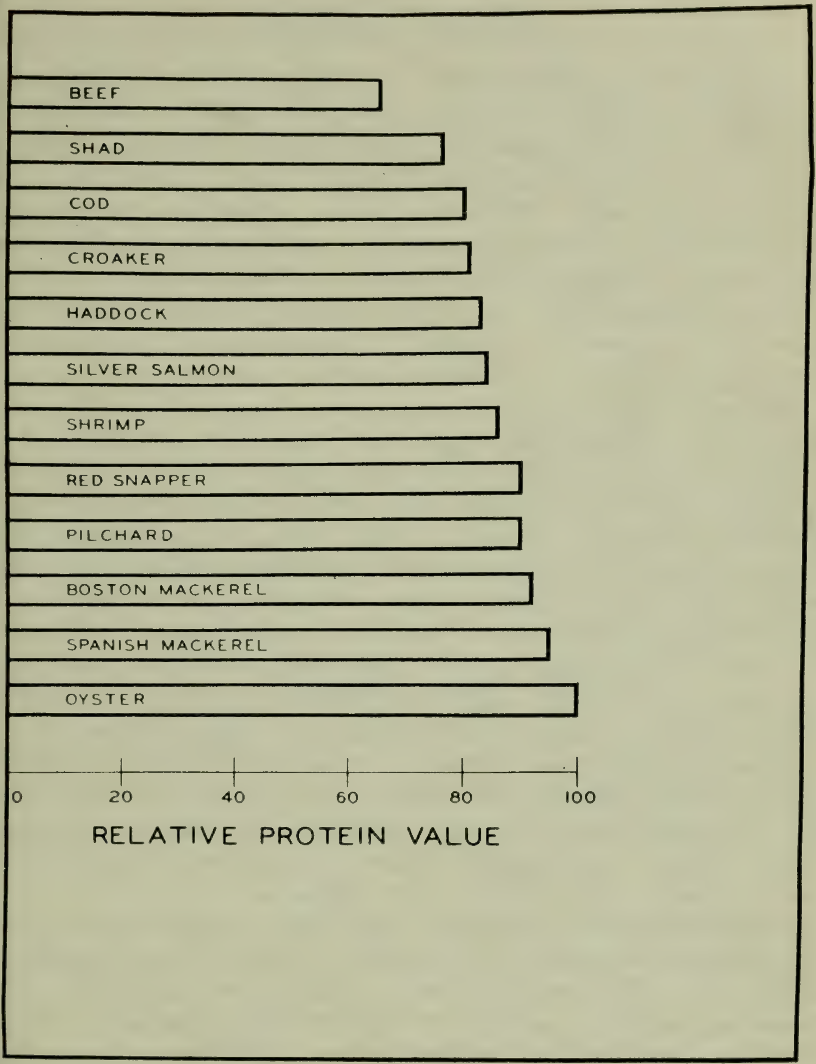

FIGURE 65.—The relative protein value of various species of fish and of beef. (After Lanham and Lemon, 1938)

o that of other fats. The apparent digestibility of oil from canned almon has been found to be 97 percent, which is about equal to hat of butter or olive oil and somewhat greater than that of beef at.

The fish oils contain vitamins A and D as well as being a source of energy. The natural fish oils should be consumed wherever possible. For this reason such procedures as the addition of salmon oil to canned Columbia River chinook salmon are commendable and should be encouraged.

MINERAL ELEMENTS

A number of mineral elements are found necessary to well being, a deficiency of these elements resulting in poor growth and development, and susceptibility to various disorders and diseases. Some of the minerals are water soluble and are partially lost in cooking fresh foods. The bony structure of fish is rich in certain essential minerals such as calcium, but in fresh fish the bone cannot be utilized. In canned fish the water soluble minerals are preserved, while any bones are softened and made entirely edible. Canned fishery products are one of our best sources of the essential minerals, providing that the entire contents of the can are used.

Mineral elements needed for the proper functioning of the body are calcium, phosphorus, magnesium, iron, iodine, copper, potassium, and sodium. The average American diet is likely to be deficient in calcium, which is necessary for the development of bones and teeth (American Can Co., 1937). Therefore a special effort should be made to include foods rich in calcium in the diet. This need is one of the principal reasons for advocating a wider use of milk in the diet of children. Canned seafoods, especially salmon, sardines, and mackerel, are a reasonably good source of calcium and are rich in iron, copper, and iodine (Nilson and Coulson, 1939), which are scarce or lacking in milk. Phosphorous is also essential for the proper formation of bones and teeth (McCollum and Simmonds, 1929). Data on mineral content of foods show that fish are a good source of phosphorus, but as this element is found in many agricultural products, the average diet is not especially liable to be deficient in phosphorus.

A lack of iodine in the diet is the cause of endemic goiter, and this element is likely to be deficient in all areas not contiguous to the coast. These areas extend notably around the Great Lakes, extending eastward into New York, south into Kentucky and Missouri, and westward to the Pacific Coast. Children are especially liable, more than 50 percent being affected in some localities, and girls are more susceptible than boys. A survey of Seattle, Washington, school children showed that at the age of 13, 70 percent of the girls and 49 percent of the boys were affected (Jarvis, Clough and Clark, 1926). Endemic goiter is prevented or cured by furnishing the iodine required to make up the deficiency either by the addition of iodine to the food or water supply or by substituting foods rich in iodine for iodine deficient foods (Jarvis, 1928). A daily intake of 0.1 mg. of iodine has been recommended by the Technical Commission of the Health Committee for the League of Nations. Seafoods are the best source of iodine for such a diet as they have from 50 to 200 times the iodine content of land products. Nutritionists have for years urged the more liberal use of sea foods in the diet, as the best means of supplying the deficiency of iodine and other minerals (Coulson, 1935). Canned seafoods are especially recommended as a source of iodine as they contain valuable amounts of the element, are obtainable everywhere, and are sold at prices permitting their use even by low income groups.

The other minerals listed are important to the regulation of many vital body processes. They are usually provided by the ordinary mixed diet, but the regular use of canned sea foods is good insurance against any probable mineral deficiency in the diet.

VITAMINS

Little is yet known as to how the vitamins function in the body. Vitamin A is necessary for normal eyesight and the daily requirement is about 1500 to 4000 international units, with children requiring more than adults in proportion to weight. McCollum and Simmonds, (1929) state that fish and other marine animals are rich in Vitamin A. Research indicates that commercially canned products do not show a loss of Vitamin A in packing and are equal to freshly cooked or raw products as a source of Vitamin A. Canned fish roe is a good source of this vitamin.

Vitamin B_1, or thiamin hydrochloride, protects against certain nervous disorders. The extreme deficiency disease is beri-beri, which is rare in the United States but symptoms of marginal deficiency are common. The daily requirement is about 300 international units for an adult man. Oysters and fish eggs, such as canned fish roe, are especially rich in Vitamin B_1.

The principal role of Vitamin D is to ensure proper calcification of the bones. Lack of this vitamin and of optimum quantities of calcium and phosphorus is one cause of rickets in children. Most common foods are deficient in Vitamin D but a number of seafoods such as herring, salmon, and sardines are classed as very good sources. The Vitamin D content of the different species of salmon has been studied by the Fish and Wildlife Service. Eliot, *et al.* (1932) found that oil from two species of commercially canned salmon had Vitamin-D potency equal to that of cod liver oil, while oil of the third species was found to be about half as potent. Study of the Vitamin-D content of salmon oil, the amount of oil found in canned salmon, and the quantity of canned salmon consumed in this country annually, led to the conclusion that this product supplies more Vitamin D than all the cod liver oil used for both human and animal feeding. Other studies indicate that herring (Maine sardines), pilchards (California sardines) and both wet and dry pack canned shrimp are definitely valuable sources of Vitamin D.

Until very recently, pellagra was thought to be mainly due to a deficiency of Vitamin G. Now it has been shown that pellagra is due to a multiple vitamin and protein deficiency, but nicotinic acid and riboflavin with which Vitamin G are identified, are of value in treatment. Very few assays of fishery products for nicotinic acid and riboflavin have been reported in recent literature, but canned salmon, flaked haddock, clams, crabs and oysters have been shown to have a pellagra preventive activity. Few assays have been conducted for the other known vitamins but preliminary experiments have shown that canned fishery products contain Vitamin K and pantothenic acid.

APPETITE APPEAL

If full use is to be made of the nutritional value of fishery products they must also be made appetizing. Other things being equal, the consumer may be educated to use products with the superior nutritive value, but if canned fishery products are not prepared so that the maximum of favorable appearance and flavor are retained, some more attractively prepared article of lower food value will be substituted. Canned fishery products are very appetizing if the proper attention is paid to quality and if they are attractively served. Every care should be taken to produce high quality packs and advertising programs should be directed to helping homemakers and other cooks prepare attractive and appetizing dishes.

AMOUNT OF WASTE

Weight for weight, the more important canned fishery products are less expensive than the more popular cuts of meat. This favorable relationship is even more marked when retail price is considered together with the comparative yield of edible material, for again canned fishery products are entirely edible while in buying meat a higher price is paid for partially inedible material.

The data in figure 66 show a comparison of the retail price of canned fishery products with various cuts of meat and other foods. At the time this study was made, 3 pounds of Maine sardines (12 cans) or 3 pounds of pink salmon could be bought at retail for the price of 1 pound of beef round. The most striking comparison indicates that the retail cost of 1 pound of beef round would purchase 4 pounds of canned herring roe, California mackerel, or sardines. Changing market conditions may alter these ratios at any time, but even at times of high retail prices canned fishery products are less expensive than meats.

VARIETY OF CHOICE

The great development in methods of preservation, transportation and storage has led the consumer to expect a much greater variety than our fathers were offered. This creates new prob-

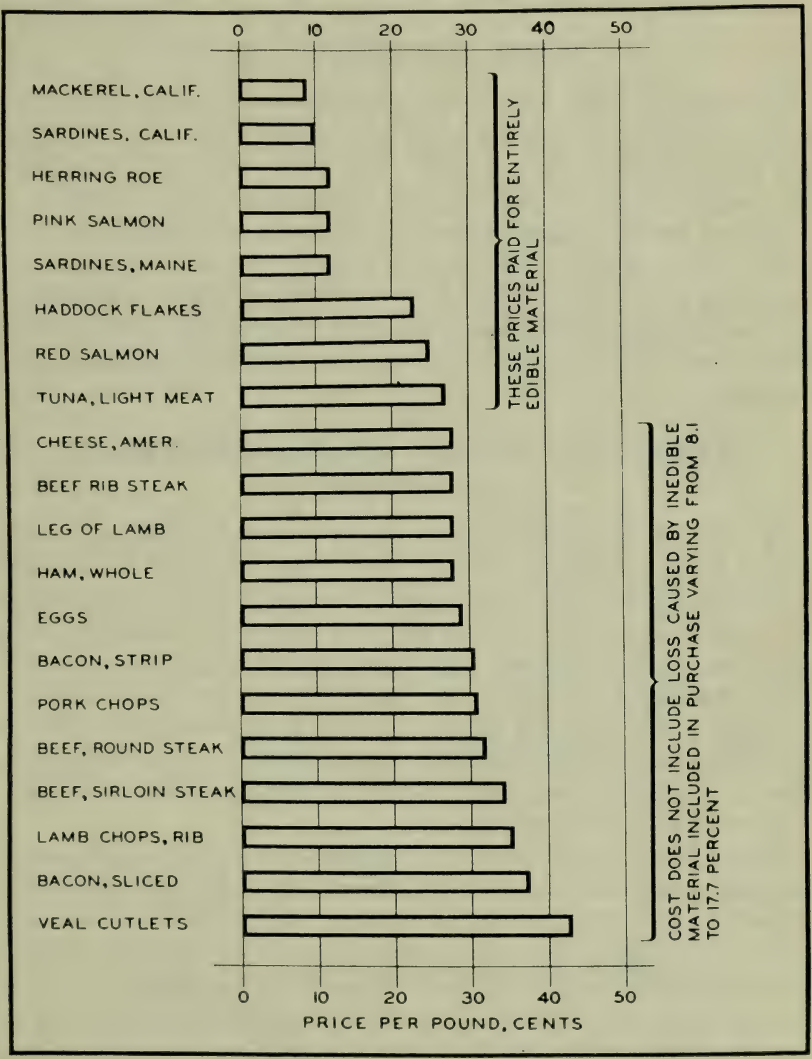

FIGURE 66.—A comparison of the prices of meat and canned fish.

lems in retailing. When handling fresh fruit, vegetables, meat or fish, the retailer expects to lose a certain amount of the product unless he has adequate refrigeration equipment. No special equipment is needed to retail canned fish, and there are no spoilage losses in handling. Even when fresh, frozen or cured fish are available there is a wide market for canned fish, especially where it is properly merchandised, because the variety of choice is increased; for example, the consumer may buy canned salmon in preference to fresh, frozen, smoked or salted salmon when all are available. The inland consumption of fish would be negligible if it were not for the use of canned fish, of which 17 varieties are distributed generally.

EASE OF PURCHASE

The sale of fresh, frozen or cured foods is restricted to those stores equipped to handle such products. Many neighborhood or country food dealers cannot afford the necessary equipment. Regular deliveries are also required if the dealer is to handle fresh or frozen foods. Canned fishery products are available to any retailer anywhere in the United States. Special equipment, irregular or poor transportation, unfavorable weather, perishability, —all the difficulties hindering the wider distribution of fresh and frozen foods are readily surmounted in marketing canned fishery products.

ABILITY TO PURCHASE IN CONVENIENT QUANTITIES

Canned fishery products meet the last of the consumer demand factors better than any other type of food, for they are available in amounts from 2½ ounces to 5 pounds. There are packages for individual use and there are containers for large scale consumption. Tin and glass containers are the most convenient consumer packages since they do not leak nor is there danger of spoilage if the package is not delivered immediately. Tin and glass containers withstand handling much better than less durable types of food packages and it is not necessary for the homemaker to store them in the refrigerator.

From all the points of view of consumer interest, canned fishery products meet his requirements more generally and under more different and difficult conditions than almost any other class of foods. Intelligent marketing and advertising methods can undoubtedly increase the present demand. Development in other methods of preservation and handling should not affect the sale of canned fishery products so long as canners endeavor to pack products of high quality.

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UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

BIG-GAME RESOURCES OF THE UNITED STATES

1937–1942

RESEARCH REPORT 8

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ABSTRACT

AN INVENTORY tabulated by States of 15 groups and races of big-game animals in the United States has been compiled annually by the Fish and Wildlife Service since 1937. These were the first attempts at a complete estimate of all big-game animals in the United States or, so far as known, in any country. Compilations for 1937, 1938, 1939, and 1940 have been issued as mimeographed wildlife leaflets.

Probably the first planned inventory of a big-game species was that by W. T. Hornaday of the American bison in 1889. From about 1920 the United States Forest Service attempted detailed annual inventories of the big game on national forest lands. A little later a few of the States made similar estimates. Methods of making game counts were developed and have been improved with study and modern equipment.

The Fish and Wildlife Service compilation for 1941 showed a total of 6,748,424 big-game animals in the United States, of which 6,089,172 were deer of all species, and 3,805,368 of these, or more than half of all big game, were white-tailed deer. Pennsylvania ranked first with 752,637 big-game animals, followed in order of numbers by Michigan with 739,521, Wisconsin with 607,627, California with 575,639, Minnesota with 485,150, and Colorado with 440,109. No State was without some big-game animals, although Delaware was represented by only 19 and Kansas by 50. The 1941 estimate showed an increase of more than 13 percent over that of 1940 in all big game in the United States.

At the close of the 5-year period, three species seemed to be in a precarious status. The number of moose had decreased throughout the United States 11.3 percent since 1937, and that of bighorn sheep 14.6 percent. The grizzly bear population had increased 12.1 percent; nevertheless, it is in constant danger of extirpation in the United States outside of national parks. The prong-horned antelope showed an increase of 51.6 percent in numbers over those of 1937; black bear, 45.1 percent; elk, 42.8 percent; deer, 30.0 percent; peccary, 23.8 percent; mountain goat, 23.6 percent; and American bison, 21.4 percent. Big game as a whole increased 30.8 percent.

On the basis of the number of big-game animals per 100 acres of land, national forests ranked first with an average of 1.49 per 100 acres. Other land-control classifications rated as to average number of big-game animals per 100 acres were: Fish and Wildlife Service refuges, 0.62; national parks and monuments, 0.50; State and private lands, 0.42; grazing districts, 0.29; Indian reservations, 0.09.

The total big-game kill for 1941 was 476,674 animals, or 8.0 percent of the previous year's population, and these were estimated to have a hog-dressed weight of 52,259,100 pounds. The total big-game kill for 1942 was 640,755 animals, or 9.5 percent of the previous year's population, with a corresponding weight of 71,013,640 pounds.

BIG-GAME RESOURCES OF THE UNITED STATES, 1937–1942

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CONTENTS

Page
iuction 1
history of big-game estimates 2
ıme inventory and sources of information 3
ı for making counts 4
methods of making counts 5
ıme inventory of the United States, 1941 6
ation trends in principal big-game animals 15
eer 16
oodland caribou 16
merican elk 21
oose 23
ong-horned antelope 25
ghorn sheep 28
ountain goat 32
ıllared peccary 34
ack bear 36
izzly bear 38
Population trends in principal big-game animals—Continued.
American bison, or buffalo 39
Introduced species 41
Population trends in big game on different land-classification areas 42
Changes in big-game populations of States, 1940–41 45
Changes in big-game populations on land-control areas 48
Fish and Wildlife Service refuges 50
National forests 50
National parks and monuments 50
Grazing districts 50
Indian reservations 51
State and private lands 51
Game kill 51
Literature cited 54

INTRODUCTION

n inventory, tabulated by States, of 15 groups and races of big-e animals in the United States, has been compiled each year since by Biological Surveys, of the Fish and Wildlife Service, from received from State and Federal agencies. The compilations been published by the Service in the following processed Wild-Leaflets: For 1937, No. 122; for 1938, No. 142; for 1939, No. 175; for 1940, No. 207. The compilation for 1941 appears in this report 6–14). From the beginning of these studies it was planned, if ient reliable data were available, to summarize results yearly and ıe close of each 5-year period to analyze the whole in order to mine population trends of the 15 big-game types on the various -control units and in the Nation as a whole. That is attempted he first pentad in this bulletin.[1]

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[1] procuring annual big-game estimates from the 48 States and the various land-control the author is indebted to many of his colleagues in the Fish and Wildlife Service, ılarly to biologists in the Division of Wildlife Research and to administrators and ıen of the regional offices and of the Division of Wildlife Refuges; to officials and ne specialists of the conservation or game commissions or departments of the several ; to officials and game managers of the Forest Service, United States Department of lture; and to officials and wildlife authorities of the Grazing Service, the National ervice, and the Office of Indian Affairs, United States Department of the Interior. acting task of summarizing the estimates and assembling and calculating the statis-ata was done by Miss Frances W. Shibley, and the skillful plotting and drawing of ıphs and charts by Mrs. Katheryne C. Tabb, both of Biological Surveys.

BRIEF HISTORY OF BIG-GAME ESTIMATES

Rough appraisals of big-game populations may possibly have b made even by primitive man. Picture words in petroglyphs, or r carvings or writings (fig. 1), made by Indians and cliff dwellers the West conveyed the information that game abounded in cert regions. Early explorers returning east during the first half of nineteenth century spoke of the "immense herds" or "countless th sands" of buffaloes and other big-game animals. There was nothi tangible in these statements, however, concerning actual numbers.

One of the first systematic attempts to take inventory of the pop lation of a big-game species over any considerable area was that Hornaday (1889: 525),[2] who, through correspondence and by oth means, estimated the total number of American buffaloes then livi in North America as 1,091. At that time there were only 541 Am ican bison in the United States, of which 200 were in Yellowsto National Park, 85 in the wild in Texas, Colorado, Wyoming, Monta and the Dakotas, and 256 owned by private individuals or in ca tivity. The count of so small a number was not very complicat Beginning in 1908 and continuing through 1934, 20 counts were ma by the American Bison Society, which was organized to save t species from extinction. The Fish and Wildlife Service later ma an estimate of the numbers of American bison in the United Sta and Alaska.[3]

About the year 1920 the need for more accurate knowledge of o big-game populations began to be recognized. The Forest Servi of the United States Department of Agriculture, at that ti attempted more detailed annual inventories of the big-game anim on the national forests, although it had made some estimates f several years previously. A very few of the States, notably New Yo (Pratt, 1918), had begun to check up on their big-game resources.

Stimulus to the making of big-game inventories was provided 1922 through publication by the Bureau of Biological Survey of bulletin on "Game as a National Resource" (Palmer, 1922). Palm estimated the total numbers of 6 species of game mammals—buffa elk, antelope, moose, mountain goat, and mountain sheep—in t United States in 1918 and 1920. His figures seem conservative. should be borne in mind, however, that the year 1920 was near t "low" population for most big-game animals in the western Unit States. In the east, particularly the northeast, the low period h been reached some 30 years earlier. "This black 1890 was the lo ebb year for nearly all kinds of big game, east of the Mississippi

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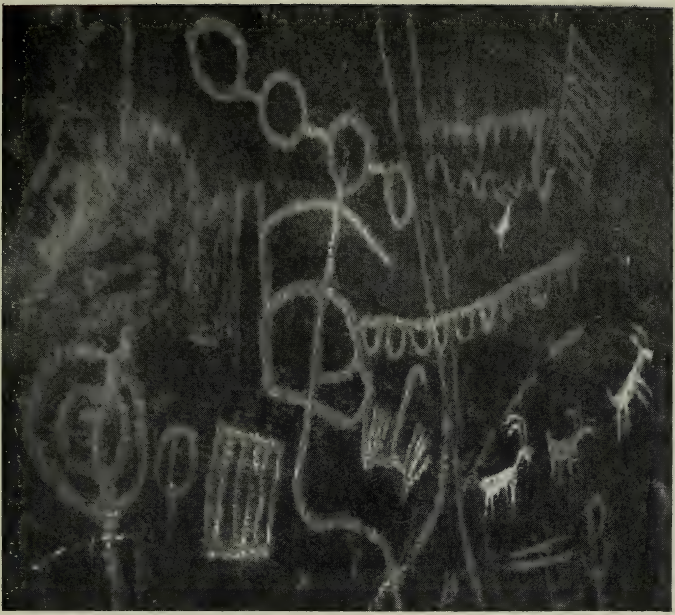
[2] Publications referred to parenthetically by date (alone or with colon and specific pa are listed in the Literature Cited, pp. 54–56.

[3] Status of the American bison in the United States and Alaska, 1939, U. S. Dept. I Bureau of Biological Survey Wildlife Leaflet 148, 10 pp., December 1939. [Processed.]



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IGURE 1.—Pueblo petroglyphs, Valley of Fire, near Overton, Nev., indicating presence of desert bighorns in the region. (Photographed July 14, 1940, by Hartley H. T. Jackson.)

eton, 1929, 3:247.) Palmer could not attempt an estimate of the mbers of that most important of big game, the deer, and passed er the caribou, the peccary, and the bears. He did focus attention the need for inventories of game animals, which he clearly showed be an important national asset.

One of the most intensive inventories of a single game species over entire range was that conducted by the Bureau of Biological Sur- y of the prong-horned antelope (Nelson, 1925). This estimate as of 22–24 indicated a total population of 30,326 pronghorns in North nerica, of which 26,604 were in the United States. Maps show the cation of the herds and the estimated number of animals in each.

BIG-GAME INVENTORY AND SOURCES OF INFORMATION

Early in the year 1938, in response to numerous requests for in- rmation on the status of several species, the Bureau of Biological irvey undertook the first Nation-wide inventory of all major big- me animals in the United States. It was foreseen that it would be large undertaking to assemble reliable information from many urces. Fifteen groups and races of such animals were included in e estimates. The data for the years 1937 and 1938[4] for State and ivate lands were compiled by States by field investigators in the ivision of Wildlife Research, and estimates for Indian reservations r these 2 years were made in Biological Surveys. Information for ate and private lands and for Indian reservations for the past three nual estimates (1939, 1940, and 1941)[5] has been collected through e regional offices of the Fish and Wildlife Service.

All the States realize the value of these estimates and most of them ake diligent effort to furnish dependable information. A few States ch year have failed to supply estimates of the game populations, cause their counts were incomplete or inaccurate, or because they d not possess a proper organization for collecting the data. There e so few important reports from military, coast guard, and light- ouse reservations that these have not been treated separately but ave been included with State and private lands. Both the Navy and e War Departments displayed cooperative spirit but deemed that ecause the numbers of big-game animals on their lands were com- aratively small and they had no machinery for taking game inven- ries, it would be better for the Fish and Wildlife Service to make the estimates. Reports issued annually by the Forest Service, of th United States Department of Agriculture, are exceptionally valuable and in a few States during some years these estimates have been th only ones available. The National Park Service, the Grazing Service and the Office of Indian Affairs, of the Department of the Interior have cooperated fully in supplying information for lands under thei control. Use has been made of statistics issued annually by th National Park Service. The Grazing Service, developing a system of taking inventories of big game on its lands, has yearly improve the accuracy of its estimates. As the Office of Indian Affairs had not until recently made game inventories, estimates of big game on Indian reservations for 1937 and 1938 were made in the Fish and Wildlife Service from reports from several sources. Estimates for these lands in 1939, 1940, and 1941 were supplied by the regiona offices of the Service from reports made directly to them by such of the various Indian agencies as had information within the respective regions. Counts of the more important wildlife species on Fish and Wildlife Service refuges are made annually by the Service.

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[4] Big-game inventory of the United States, 1937, U. S. Dept. Agr., Bureau of Biological rvey Wildlife Research and Management Leaflet BS–122, 13 pp., January 1939 [processed]; d Big-game inventory of the United States, 1938, U. S. Dept. Int., Bureau of Biological rvey Wildlife Leaflet BS–142, 11 pp., August 1939 [processed].

[5] Big-game inventory of the United States, 1939, Fish and Wildlife Service Wildlife aflet 175, 11 pp., November 1940 [processed]; and Big-game inventory of the United ates, 1940, Fish and Wildlife Service Wildlife Leaflet 207, 10 pp., January 1942 rocessed].

In the majority of the States efforts were made to procure really dependable information. The figures have been criticized by some individuals who considered the estimates either too high or too low, and by officials of certain States who had no figures of their own to release The fact that in several instances the same figure was criticized by different individuals as being both too high and too low makes it appear that the estimates have at least average accuracy. As the inventories continued through the 5-year period, criticism diminished. Advantage has been taken of the various criticisms and suggestions, and a few of the figures published in the earlier inventories have been corrected for use in the present report.

SEASON FOR MAKING COUNTS

Although the last day of each calendar year has been indicated as the preferred time for game counts, as a matter of fact any time may be satisfactory after the hunting season and before the young are born, and preferably while the animals are still on their winter range. Of the huntable species, the greatest number exists after the young have arrived late in the spring or early in the summer. From this number there will be losses from hunting, disease, starvation predation, and other causes. The best time for enumerating bears bighorns, mountain goats, and possibly moose and caribou, is early in the spring. Winter counts are better for species that tend to form herds or to "yard" at that season. After deciduous trees have shed their leaves is, in most places, the proper time for counts of deer and elk. Although estimates are labeled by calendar years, part of the actual counts may have been made early in the following spring. Thus the 1937 inventory, as of December 31, 1937, may have been estimated from cumulative counts made on various areas from December 1, 1937, to April 15, 1938.

Making counts of the animals while they are on their winter range and not migrating tends to eliminate duplications. Several corrections in the estimates, particularly for 1937 and 1938, were made as a result of comparing the actual times of the counting on adjoining areas. It is believed that in most instances the estimates, especially for the last 2 years, are reasonably accurate and that duplication to any considerable extent has been eliminated.

SOME METHODS OF MAKING COUNTS

Methods of making a count of big-game animals on a given area or on a major land unit may vary to meet the situation. Palmer (1922: 48) suggested that for States to require "each big-game hunter to make a return of the results of his activities under his license, as is now done in several States and Canadian Provinces, would give accurate figures of the total number of deer and other big game annually killed." Some of the States undertook this system of estimating the numbers of deer as far back as 1918. In New York the first record of game taken was attempted in 1915 through the game protectors. In 1918 a system of getting the reported take of game was instituted through requiring a report on the license stub to be filled out by the license clerk in accordance with statements made by the licensee when making application for the next year's license (Whipple, 1935: 123). From these figures could be computed approximately the big-game populations of the State, which were later summarized by Skiff (1938). Fourteen States were in 1935 reporting the number of deer killed. By 1942 nearly all States had some system of determining the number of deer taken by hunters. Apparently about 10 percent of the big-game population is killed during an average hunting season. Few estimates of populations used in this report have been computed from hunter returns. The method, however, has been used to aid by comparison in the verification of estimates.

The fact that many of the big-game totals are given in definite numbers does not imply that an accurate count was made of individual animals. Small areas where it was possible to count accurately the few individuals were included with other areas, and in many of these cases the individuals were so few that estimates to the nearest round number would be misleading.

Research upon improving methods of making big-game counts is in progress. Many techniques, however, have already been developed, and generalized statements of these are available (Bell, 1937; [Bray], 1938;[6] Dice, 1941; McLean, 1940; Ruhl, 1932). Considerable has also recently been written on special methods adaptable for particular species, regions, or environments, or for unusual conditions (Adams, 1938; Baker and Siegler, 1943; Bennett, English, and McCain, 1940; Cahalane, 1938; Erickson, 1940; Hickel and Swift, 1943; Krefting and Fletcher, 1941; McCain, 1939; McCutchen, 1938; Morse, 1943; Olsen, 1938; Rasmussen, 1939; Saugstad, 1942; Schwan and Swift, 1941; and Wright and Swift, 1942). Accurate counts of most ungulate mammals can now be made on areas of several hundred acres. Reasonably accurate estimates can be made for larger areas by taking counts on carefully selected small sample areas that represent average conditions. For all of our big-game species, except the bears, direct enumeration by counting on sample or entire areas is the approved system. Details of making the enumeration may vary, and in any event check counts should be made by more than one method in order to test the efficiency and accuracy of a system. In many regions without heavy forest cover or in deciduous woodland in winter, the airplane count has proved successful, especially for the deer, elk, caribou, prong-horned antelope, bighorn sheep, mountain goat, and buffalo. Ground counts may be made over a total range or on sample parts of it by men assigned to particular areas. In making such counts, travel may be on horseback, especially for buffaloes, but also for elk, deer, and antelopes, and on skis or snowshoes for counting any of the ungulate species except the dangerous buffalo. Travel on foot is often the most satisfactory method, especially for bighorn sheep and mountain goats. The "drive" method is frequently used for counting deer. Pellet-group counts also are employed in making deer estimates and may be used for other species. Counts in woodland are often best made at winter concentration points, and those in arid regions at the watering places of the animals. Population estimates of bears can sometimes be made by counting the animals on their feeding grounds. As a rule, however, in dealing with these animals, resort must be had to locating dens, tracks, and claw marks on trees, in addition to making such direct enumeration as may be possible.

BIG-GAME INVENTORY OF THE UNITED STATES, 1941

In assembling the information for the big-game inventory of December 31, 1941, tables 1–17, use has been made, as in previous years, of statistics issued annually by the Forest Service and by the National Park Service. The Grazing Service and the Office of Indian Affairs have cooperated fully in supplying information for their lands. On efuges of the Fish and Wildlife Service counts of important wildlife pecies are made annually by the Division of Wildlife Refuges. The ata for State and private lands, as well as most of those for Indian eservations, were assembled and arranged by the five regional offices f the Fish and Wildlife Service.

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[6] Wildlife census methods applicable to national parks and monuments, compiled by Robert S. Bray, student technician, U. S. Dept. Int., National Park Service leaflet, 17 pp. [September 1938]. [Processed.]

It is interesting to note that every big-game species except the rizzly bear and the European wild boar showed an increase in 1941 ver 1940. This increase of more than 13 percent for all big game is ignificant and may possibly indicate a decreased hunting pressure. hat is more probable, however, is that it reflects the influence of the 941 growing season of favorable rainfall and abundant forage and rowse, particularly in the Western States.

TABLE 1.—*White-tailed deer* (Odocoileus virginianus) *and related groups*

State	Service refuges	National forests	National parks and monuments	Indian reservations	Grazing districts	State and private lands	Total
labama		1, 400				13, 646	15, 046
izona		25, 000	435	2, 675	200	2, 000	30, 310
kansas	2, 000	6, 900				12, 960	21, 860
nnecticut						5, 700	5, 700
elaware	4					15	19
orida	110	8, 050		200		17, 800	26, 160
orgia	1, 757	1, 700				12, 795	16, 252
aho		20, 000		285		7, 805	28, 090
inois		10				350	360
diana		35				2, 200	2, 235
wa						1, 250	1, 250
ansas						[1] 15	15
ntucky	400	6				652	1, 058
uisiana	818	70				17, 000	17, 888
aine	1, 500	95	2, 300			107, 899	111, 794
aryland						5, 500	5, 500
assachusetts						[1] 11, 000	11, 000
ichigan	2, 000	168, 000		200		564, 000	734, 200
innesota	1, 461	94, 000		3, 252		373, 790	472, 503
ississippi		475				9, 604	10, 079
issouri		3, 000				3, 745	6, 745
ontana	177	26, 000	1, 700	908	920	10, 000	39, 705
braska	9					200	209
w Hampshire		1, 500				26, 200	27, 700
w Jersey						12, 350	12, 350
w Mexico		14, 000		350	150	2, 100	16, 600
w York	60					300, 000	300, 060
rth Carolina	62	7, 915		2		59, 000	66, 979
rth Dakota	2, 086			405		3, 803	6, 294
io		30				3, 600	3, 630
lahoma	639	500		3, 151		4, 000	8, 290
egon		110		10		380	500
nnsylvania		16, 000				734, 000	750, 000
ode Island						600	600
uth Carolina	210	2, 690				60, 100	63, 000
uth Dakota	85	7, 000		610		1, 900	9, 595
nnessee		2, 000	30			2, 940	4, 970
xas	4, 000	700				250, 000	254, 700
rmont	4	4, 900				23, 500	28, 404
rginia	6	4, 300	50			13, 243	17, 599
ashington	4, 510	9, 300		2, 400		20, 000	36, 210
est Virginia		9, 400				22, 884	32, 284
isconsin	1, 575	121, 000		2, 050		[1] 480, 000	604, 625
yoming		2, 800		200			3, 000
Total	23, 473	558, 886	4, 515	16, 698	1, 270	3, 200, 526	3, 805, 368

Estimated in Biological Surveys. No report received.

TABLE 2.—*Mule deer* (Odocoileus hemionus *except* columbianus)

State	Service refuges	National forests	National parks and monuments	Indian reservations	Grazing districts	State and private lands	Total
Arizona	100	37, 000	732	1, 405	1, 650	10, 000	50, 8
California	78	244, 000	18, 950	[1] 1, 500	10, 500	50, 400	325, 4
Colorado		143, 000	2, 150		148, 225	105, 000	398, 3
Idaho	9	92, 000	50	28	12, 920	33, 120	138, 1
Montana	359	69, 000	1, 300	1, 554	4, 495	25, 000	101, 7
Nebraska	7	700				2, 000	2, 7
Nevada	3, 400	47, 000			26, 200	[1] 16, 000	92, 6
New Mexico	810	54, 000	301	1, 108	9, 400	32, 000	97, 6
North Dakota	2			68		580	6
Oregon	4, 100	145, 000	30	5, 750	18, 460	24, 060	197, 4
South Dakota		3, 800	60	70		700	4, 6
Texas						18, 000	18, 0
Utah		144, 000	1, 040	1, 000	76, 811		222, 8
Washington	75	54, 000		1, 650		120, 000	175, 7
Wyoming	22	49, 000	1, 450	800	9, 750		61, 0
Total	8, 962	1, 082, 500	26, 063	14, 933	318, 411	436, 860	1, 887, 7

[1] Estimated in Biological Surveys. No report received.

TABLE 3.—*Columbian black-tailed deer* (Odocoileus hemionus columbianus)

State	Service refuges	National forests	National parks and monuments	Indian reservations	State and private lands	Total
California		166, 000	600	375	47, 000	213, 9
Oregon	15	40, 000	80	312	32, 093	72, 5
Washington	120	16, 000	2, 150	1, 330	90, 000	109, 6
Total	135	222, 000	2, 830	2, 017	169, 093	396, 0

TABLE 4.—*Woodland caribou* (Rangifer caribou)

State	National forests	State and private lands	Total
Minnesota		15	
Washington	10		
Total	10	15	

TABLE 5.—*Elk* (Cervus canadensis)

State	Service refuges	National forests	National parks and monuments	Indian reservations	Grazing districts	State and private lands	Tota
Arizona		4, 300		750	50	25	5,
Arkansas		75				15	
California		460			200	460	1,
Colorado		23, 000	1, 510		850	1, 000	26,
Idaho	1	26, 000		5	2, 812	9, 035	37,
Michigan		1				350	
Minnesota						130	
Montana	87	23, 000	2, 600	325	611	500	27,
Nebraska	36						
Nevada	17	250					
New Hampshire						275	
New Mexico		1, 200			3	2, 500	3,
New York						200	

TABLE 5.—*Elk* (Cervus canadensis)—Continued

State	Service refuges	National forests	National parks and monuments	Indian reservations	Grazing districts	State and private lands	Total
rth Carolina		3					3
rth Dakota	12					25	37
ahoma	187					20	207
gon	70	27,000		5	50	375	27,500
nsylvania						12	12
th Dakota		380	160	250		2,000	2,790
as						400	400
h		5,000			252		5,252
ginia		50				100	150
shington	2	13,000	4,525	110		15,000	32,637
consin		1				40	41
oming	11,000	37,000	16,050	300	775		65,125
Total	11,412	160,720	24,845	1,745	5,603	32,462	236,787

TABLE 6.—*Moose* (Alces americana)

State	Service refuges	National forests	National parks and monuments	Indian reservations	Grazing districts	State and private lands	Total
rado		1					1
o		1,000				109	1,109
ie	2	2				2,279	2,283
igan		10	250			25	285
iesota	10	500		50		830	1,390
tana	15	2,500	350	10	90	100	3,065
Hampshire		5				45	50
iont						2	2
onsin		5					5
ming	25	2,800	815	10			3,650
Total	52	6,823	1,415	70	90	3,390	11,840

TABLE 7.—*Prong-horned antelope* (Antilocapra americana)

State	Service refuges	National forests	National parks and monuments	Indian reservations	Grazing districts	State and private lands	Total
ia	60	5,900	255	35	180	2,000	8,430
rnia	56	3,500			5,000	6,700	15,256
ido		130			300	6,000	6,430
	60	6,300			9,800	[1] 1,000	17,160
ana	593	700		63	10,181	12,000	23,537
ska	40					1,000	1,040
la	8,600	330			9,725	[1] 2,800	21,455
Mexico		2,100	23	487	11,725	16,000	30,335
Dakota				27		747	774
oma	46					30	76
1	2,150	2,100		55	19,050	3,145	26,500
Dakota		520	110	233		12,500	13,363
						9,000	9,000
		250	6		1,670		1,926
ngton		2				44	46
ing	200	1,400	907	800	20,750		24,057
Total	11,805	23,232	1,301	1,700	88,381	72,966	199,385

imated in Biological Surveys. No report received.

TABLE 8.—*Rocky Mountain bighorn* (Ovis canadensis canadensis *and* O. c. sierra

State	Service refuges	National forests	National parks and monuments	Indian reservations	Grazing districts	State and private lands	Total
Arizona			50				
California		200					
Colorado		1,700	330			770	2,
Idaho		2,200			847		3,
Montana	14	960	200	40			1,
New Mexico						6	
Oregon	16	30					
South Dakota						25	
Utah		20	50		350		
Washington		20					
Wyoming		2,000	320	20			2,
Total	30	7,130	950	60	1,197	801	10,

TABLE 9.—*Desert bighorn* (Ovis canadensis nelsoni, O. c. gaillardi, *and* O. c. texianus)

State	Service refuges	National forests	National parks and monuments	Indian reservations	Grazing districts	State and private lands	Tota
Arizona	167	210	485	233	275	100	1,
California		300	590		450		1,
Nevada	812	240			900		1,
New Mexico	30	30			150	75	
Texas						110	
Total	1,009	780	1,075	233	1,775	285	5,

TABLE 10.—*Mountain goat* (Oreamnos americanus)

State	National forests	National parks and monuments	Indian reservations	Grazing districts	State and private lands	Total
Idaho	3,600			923	527	5,
Montana	4,000	950	500			5,
South Dakota	45					
Washington	5,400	450				5,
Total	13,045	1,400	500	923	527	16,

TABLE 11.—*Peccary, or javelina* (Pecari angulatus)

State	Service refuges	National forests	National parks and monuments	Indian reservations	Grazing districts	State and private lands	Tota
Arizona	100	7,100	1,250	2,170	500	4,500	15,
New Mexico		400					
Texas	100					38,000	38,
Total	200	7,500	1,250	2,170	500	42,500	54,

TABLE 12.—*European wild boar* (Sus scrofa)

State	National forests	Indian reservations	State and private lands	Total
alifornia	100		250	350
entucky			20	20
ew Hampshire			200	200
orth Carolina	150	12		162
ennessee	500			500
Total	750	12	470	1, 232

TABLE 13.—*Black bear* (Euarctos americanus)

State	Service refuges	National forests	National parks and monuments	Indian reservations	Grazing districts	State and private lands	Total
labama						300	300
rizona		950	8	670			1, 628
kansas	12	5				16	33
alifornia		13, 000	880	90		4, 000	17, 970
olorado		5, 000	64			1, 000	6, 064
orida	10	167				440	617
eorgia	300	16				300	616
aho		6, 000		15	[1] 500	5, 961	12, 476
entucky						30	30
ouisiana						500	500
aine	5	30				[1] 4, 000	4, 035
ichigan	15	1, 600		70		3, 000	4, 685
innesota	13	2, 200		288		8, 611	11, 112
ississippi						5	5
ontana	10	6, 100	400	695		1, 000	8, 205
ew Hampshire		320				600	920
ew Mexico		1, 400	12	185	630	1, 300	3, 527
ew York						1, 000	1, 000
orth Carolina	6	839		12		7, 000	7, 857
io						14	14
egon	4	6, 100	50	115		2, 281	8, 550
nnsylvania		270				2, 230	2, 500
uth Carolina						596	596
nnessee		220	250			100	570
xas						300	300
ah		480	3				483
rmont		600				450	1, 050
rginia		580				190	770
ashington	40	9, 500	185	1, 954		[1] 2, 000	13, 679
est Virginia		790				570	1, 360
isconsin		1, 800		256		900	2, 956
yoming	2	2, 800	610	100			3, 512
Total	417	60, 767	2, 462	4, 450	1, 130	48, 694	117, 920

[1] Estimated in Biological Surveys. No report received.

TABLE 14.—*Grizzly bear* (Ursus horribilis)

State	National forests	National parks and monuments	Indian reservations	State and private lands	Total
olorado	5				5
aho	46				46
ontana	500	100	50		650
ew Mexico	2			1	3
ashington	6				6
yoming	220	310	3		533
Total	779	410	53	1	1, 243

TABLE 15.—*American bison, or buffalo* (Bison bison)

State	Service refuges	National parks and monuments	Indian reservations	Grazing districts	State and private lands	Total
Arizona				200		20
Colorado		24			50	7
Kansas					35	3
Montana	641		600			1, 24
Nebraska	137					13
New Hampshire					6	
New Mexico			9		75	8
North Dakota	16				109	12
Oklahoma	521	6			200	72
Pennsylvania					125	12
South Dakota		135	300		400	83
Texas					250	25
Utah				21		2
Wyoming		1, 120				1, 12
Total	1, 315	1, 285	909	221	1, 250	4, 98

TABLE 16.—*Big-game inventory according to land ownership or control*

Species	Service refuges	National forests	National parks and monuments	Indian reservations	Grazing districts	State and private lands	Total
White-tailed deer	23, 473	558, 886	4, 515	16, 698	1, 270	3, 200, 526	3, 805, 36
Mule deer	8, 962	1, 082, 500	26, 063	14, 933	318, 411	436, 860	1, 887, 72
Columbian black-tailed deer	135	222, 000	2, 830	2, 017		169, 093	396, 07
Woodland caribou		10				15	2
Elk	11, 412	160, 720	24, 845	1, 745	5, 603	32, 462	236, 78
Moose	52	6, 823	1, 415	70	90	3, 390	11, 84
Prong-horned antelope	11, 805	23, 232	1, 301	1, 700	88, 381	72, 966	199, 38
Rocky Mountain bighorn	30	7, 130	950	60	1, 197	801	10, 16
Desert bighorn	1, 009	780	1, 075	233	1, 775	285	5, 15
Mountain goat		13, 045	1, 400	500	923	527	16, 39
Peccary, or javelina	200	7, 500	1, 250	2, 170	500	42, 500	54, 12
European wild boar		750		12		470	1, 23
Black bear	417	60, 767	2, 462	4, 450	1, 130	48, 694	117, 92
Grizzly bear		779	410	53		1	1, 24
American bison, or buffalo	1, 315		1, 285	909	221	1, 250	4, 98
Total	58, 810	2, 144, 922	69, 801	45, 550	419, 501	4, 009, 840	6, 748, 42

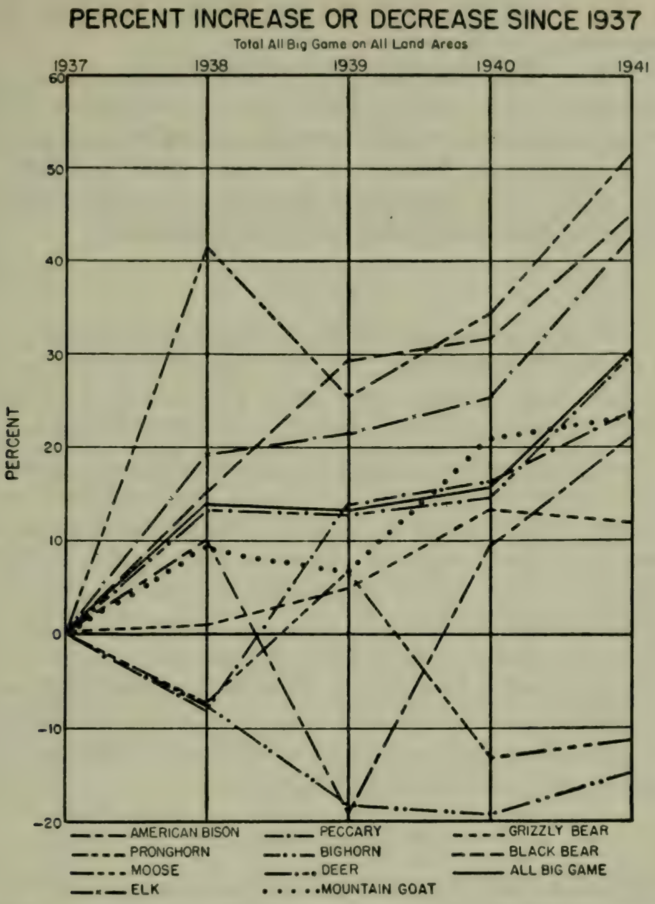
State	White-tailed deer	Mule deer	Columbian black-tailed deer	Woodland caribou	Elk	Moose	Prong-horned antelope	Rocky Mountain bighorn	Desert bighorn	Mountain goat	Peccary, or javelina	European wild boar	Black bear	Grizzly bear	American bison, or buffalo	Total
Alabama	15, 046												300			15, 346
Arizona	30, 310	50, 887			5, 125		8, 430	50	1, 470		15, 620		1, 628		200	113, 720
Arkansas	21, 860				90								33			21, 983
California		325, 428	213, 975		1, 120		15, 256	200	1, 340			350	17, 970			575, 639
Colorado		398, 375			26, 360	1	6, 430	2, 800					6, 064	5	74	440, 109
Connecticut	5, 700															5, 700
Delaware	19															19
Florida	26, 160												617			26, 777
Georgia	16, 252												616			16, 868
Idaho	28, 090	138, 127			37, 853	1, 109	17, 160	3, 047		5, 050			12, 476	46		242, 958
Illinois	360															360
Indiana	2, 235															2, 235
Iowa	1, 250															1, 250
Kansas	15														35	50
Kentucky	1, 058											20	30			1, 108
Louisiana	17, 888												500			18, 388
Maine	111, 794					2, 283							4, 035			118, 112
Maryland	5, 500															5, 500
Massachusetts	11, 000															11, 000
Michigan	734, 200				351	285							4, 685			739, 521
Minnesota	472, 503			15	130	1, 390							11, 112			485, 150
Mississippi	10, 079												5			10, 084
Missouri	6, 745															6, 745
Montana	39, 705	101, 708			27, 123	3, 065	23, 537	1, 214		5, 450			8, 205	650	1, 241	211, 898
Nebraska	209	2, 707			36		1, 040								137	4, 129
Nevada		92, 600			267		21, 455		1, 952							116, 274
New Hampshire	27, 700				275	50						200	920		6	29, 151
New Jersey	12, 350															12, 350
New Mexico	16, 600	97, 619			3, 703		30, 335	6	285		400		3, 527	3	84	152, 562
New York	300, 060				200								1, 000			301, 260
North Carolina	66, 979				3							162	7, 857			75, 001
North Dakota	6, 294	650			37		774								125	7, 880
Ohio	3, 630												14			3, 644
Oklahoma	8, 290				207		76								727	9, 300
Oregon	500	197, 400	72, 500		27, 500		26, 500	46					8, 550			332, 996
Pennsylvania	750, 000				12								2, 500		125	752, 637
Rhode Island	600															600
South Carolina	63, 000												596			63, 596
South Dakota	9, 595	4, 630			2, 790		13, 363	25		45					835	31, 283
Tennessee	4, 970											500	570			6, 040

TABLE 17.—*Summary by States of big-game animals in annual inventory, 1941*— Continued

State	White-tailed deer	Mule deer	Columbian black-tailed deer	Woodland caribou	Elk	Moose	Prong-horned antelope	Rocky Mountain bighorn	Desert bighorn	Mountain goat	Peccary, or javelina	European wild boar	Black bear	Grizzly bear	American bison, or buffalo	Total
Texas	254, 700	18, 000			400		9, 000		110		38, 100		300		250	320, 860
Utah		222, 851			5, 252		1, 926	420					483		21	230, 953
Vermont	28, 404					2							1, 050			29, 456
Virginia	17, 599				150								770			18, 519
Washington	36, 210	175, 725	109, 600	10	32, 637		46	20		5, 850			13, 679	6		373, 783
West Virginia	32, 284												1, 360			33, 644
Wisconsin	604, 625				41	5							2, 956			607, 627
Wyoming	3, 000	61, 022			65, 125	3, 650	24, 057	2, 340					3, 512	533	1, 120	164, 359
Total	3, 805, 368	1, 887, 729	396, 075	25	236, 787	11, 840	199, 385	10, 168	5, 157	16, 395	54, 120	1, 232	117, 920	1, 243	4, 980	6, 748, 424

POPULATION TRENDS IN PRINCIPAL BIG-GAME ANIMALS

The 15 big-game animals enumerated in the annual estimates include the three groups of deer (white-tailed, mule, and black-tailed), the woodland caribou, elk, moose, prong-horned antelope, two groups of ghorn sheep (the Rocky Mountain and the desert), the mountain oat, the peccary or javelina, the introduced European wild boar, black nd grizzly bears, and the American bison. In the statistical analyses nd the graph of leading species (fig. 2), because of their small num-



IGURE 2.—Percentage increase or decrease in numbers of each major species of big game in the United States from 1937 to 1941. Note the decline in bighorns and moose. All others were holding their own, with the grizzly bear apparently achieving nearly a 12-percent increase. The apparent drop in buffaloes in 1939 was occasioned by taking out of the count all animals in city and zoological parks and on private ranges. Those on private ranges were restored to the count in 1940.

bers and limited land-control distribution, the caribou and the European wild boar are omitted, the latter also because it is an exotic. Both species are, however, included in all total game estimates and analyses. Several unusual, or possibly abnormal, fluctuations occur, which appear even more pronounced in the charts and graphs than in the figures. The reasons for most of these extreme variations are given in the legends to the figures.

The inventory is restricted to wild animals of the open range or in semiconfinement. This means largely the animals subject to management though in a different sense from the management of livestock on farms. The inventory (except for the years 1937 and 1938 for the American bison) does not include animals in zoological parks or in semicaptive herds used for public or private exhibitions.

Deer

Deer of the several species constitute the most important big-game animals in the United States. In 1941, out of 6,747,192 native big-game animals in the country, 6,089,172, or 90.2 percent, were deer (figs. 3, 4, and 5). Although the distribution of deer has shrunk to less than 25 percent of their ancestral range in the United States, these animals still persist under circumstances that would eliminate most other big-game species. Deer reached a low in the United States about the year 1915, when there were possibly somewhat more than 3,000,000 in the country. With a few minor exceptions, they increased in numbers rather steadily on all land-control areas during the 5-year period, 1937 to 1941 (fig. 6), and showed a total increase of 30 percent (fig. 2). The increase showed a tendency to be more persistent and somewhat greater with the white-tailed deer than with either the mule deer or the black-tailed deer, the last two of which seem to have decreased in 1939 under 1938, but later began to recover.

Woodland Caribou

The woodland caribou even in its original range was found in the United States in only a few parts of the Northern States. It disappeared from Maine in 1916, where at one time it was probably the most abundant of any place within the United States. A considerable herd in the Red Lake region of Minnesota, numbering up to possibly a few hundred caribou in the late nineties, dwindled to 3 in 1937. The number was increased in 1938 by the introduction of 9 animals from Saskatchewan, 8 of which survived. Latest reports indicate that the herd now consists of 15 animals. Ten mountain caribou were still on the Kaniksu National Forest in Pend Oreille County, Wash., in 1941.

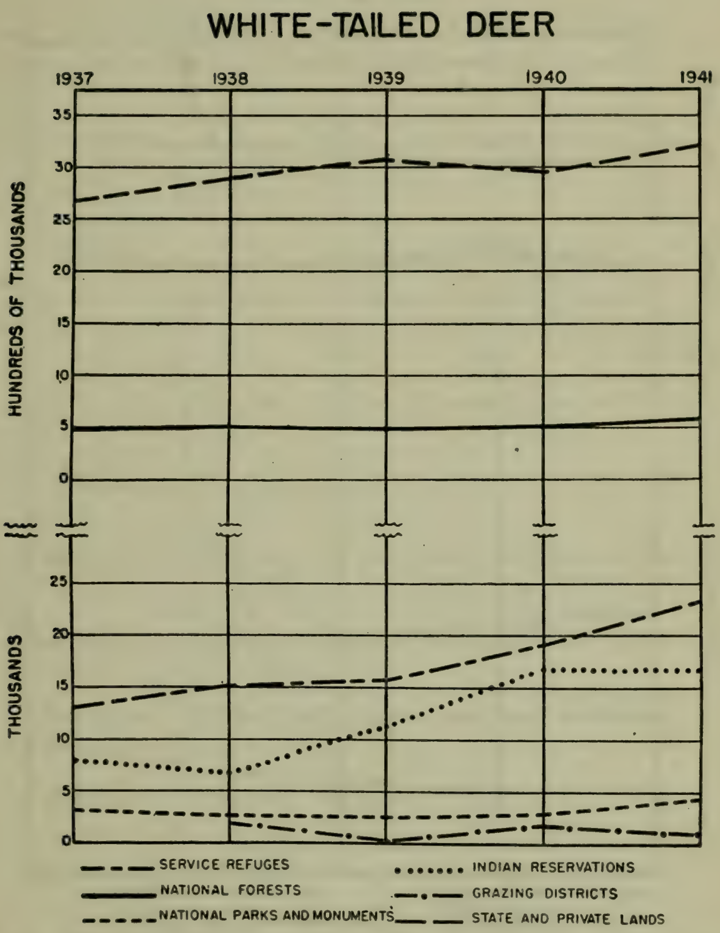


FIGURE 3.—Populations of white-tailed deer on different land-classification areas, 1937 to 1941.

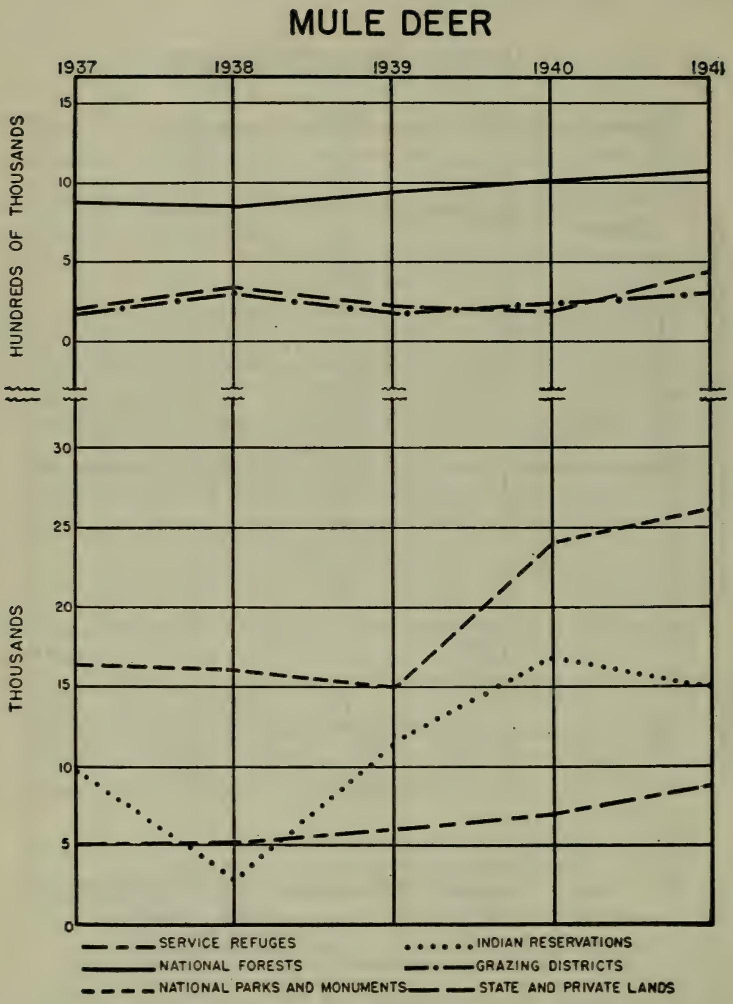


FIGURE 4.—Populations of mule deer on different land-classification areas, 1937 to 1941.

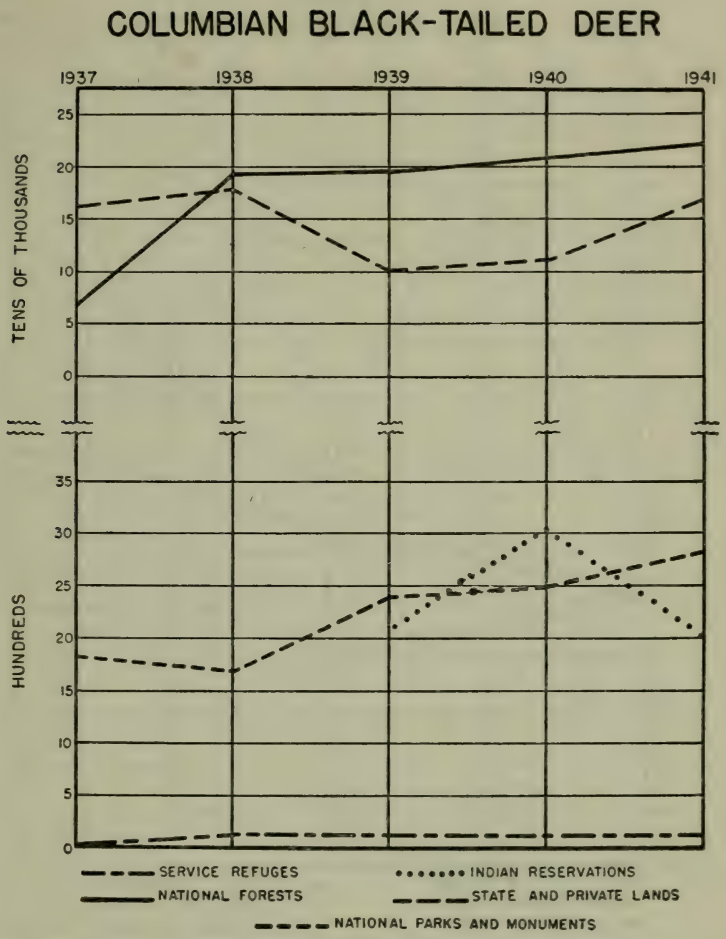


FIGURE 5.—Populations of Columbian black-tailed deer on different land-classification areas, 1937 to 1941.

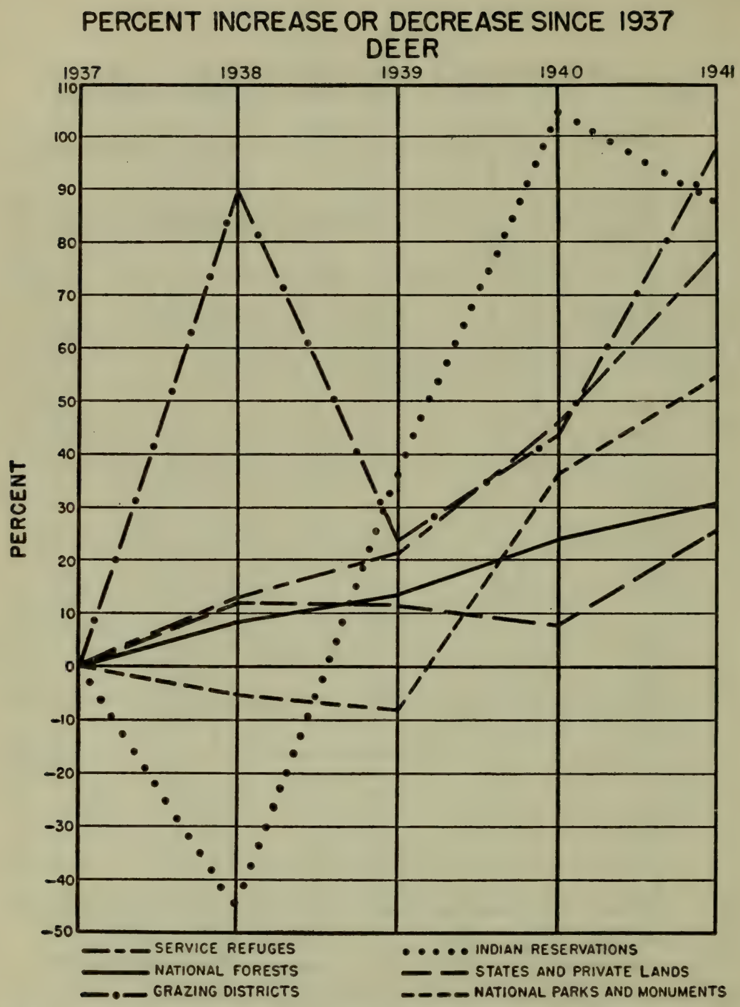


FIGURE 6.—Percentage increase or decrease, 1937 to 1941, in numbers of deer of all species on different land-classification areas. The drop in 1938 on Indian reservations was occasioned by an ultraconservative estimate for that year.

American Elk

At the time of the early American colonists, the American elk, or wapiti, occurred in all except 6 of the present States of the Union. Having a high food value and an excellent hide, it soon succumbed to the encroachment of civilization, and by 1910 it was reduced from

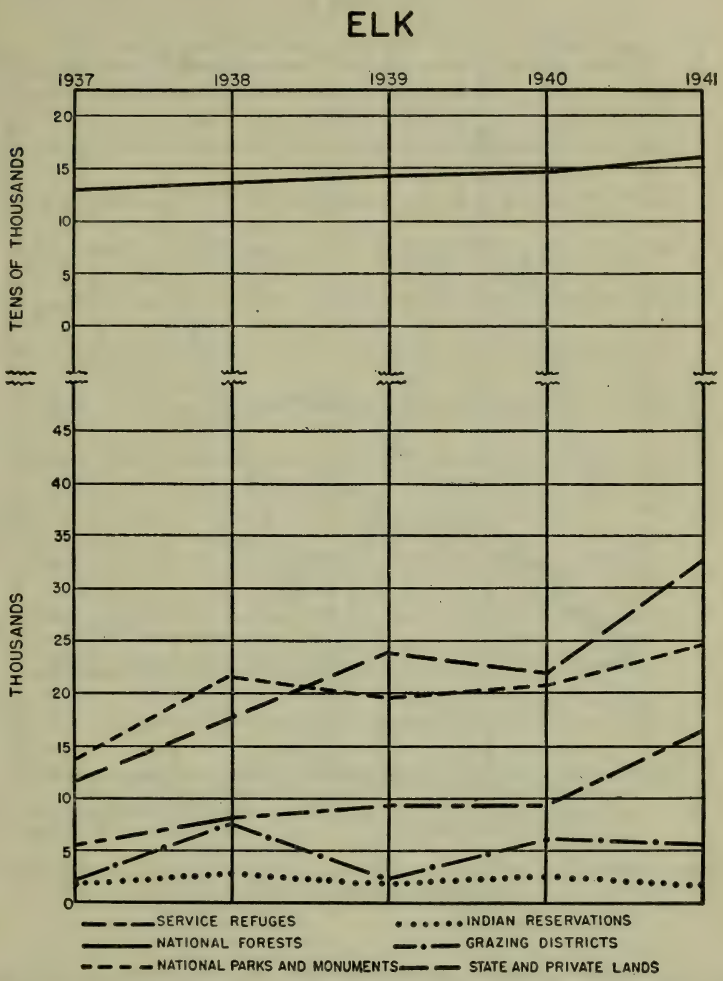


Figure 7.—Populations of elk on different land-classification areas, 1937 to 1941.

he original millions to some 60,000 in not more than 7 States. Beginning experimentally about that year and becoming really active n 1912 (Palmer, 1922: 40), introductions of elk were made into many f the States, most of the stock coming from Yellowstone National

Park[7] or the National Elk Refuge in Wyoming. Today elk occur in 25 States and in 1942 were considered huntable game in 11 States The increase in numbers of elk in the United States may be summarized as 52,000 in 1920 (Palmer, 1922: 24); 165,764 in 1937; and 236,787 in 1941. The increase in numbers and percentage is shown in figures 7 and 8.

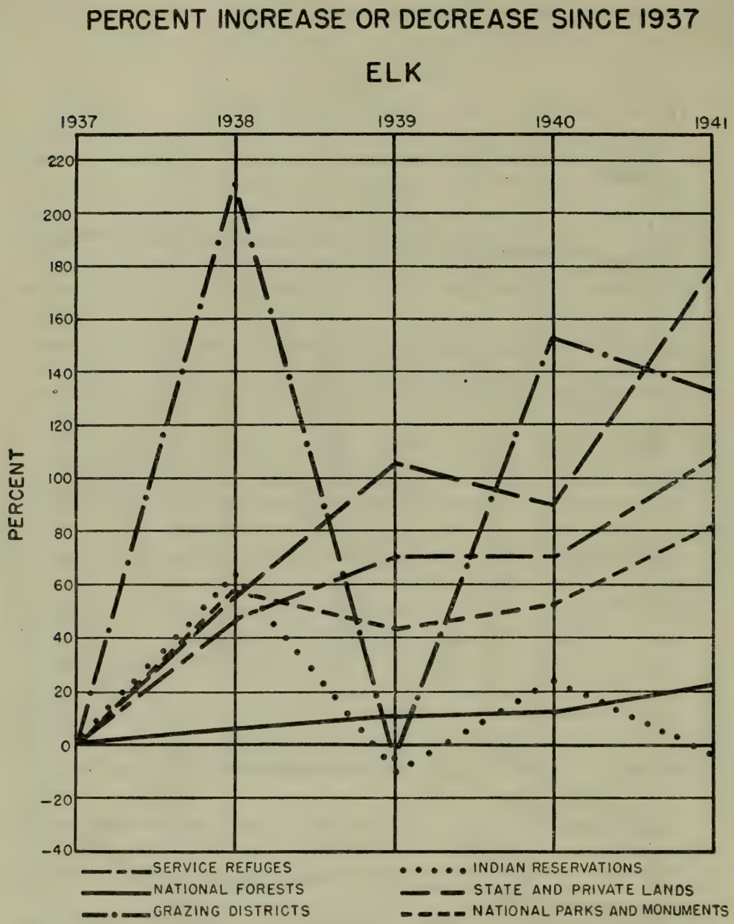


FIGURE 8.—Percentage increase or decrease, 1937 to 1941, in numbers of elk on different land-classification areas.

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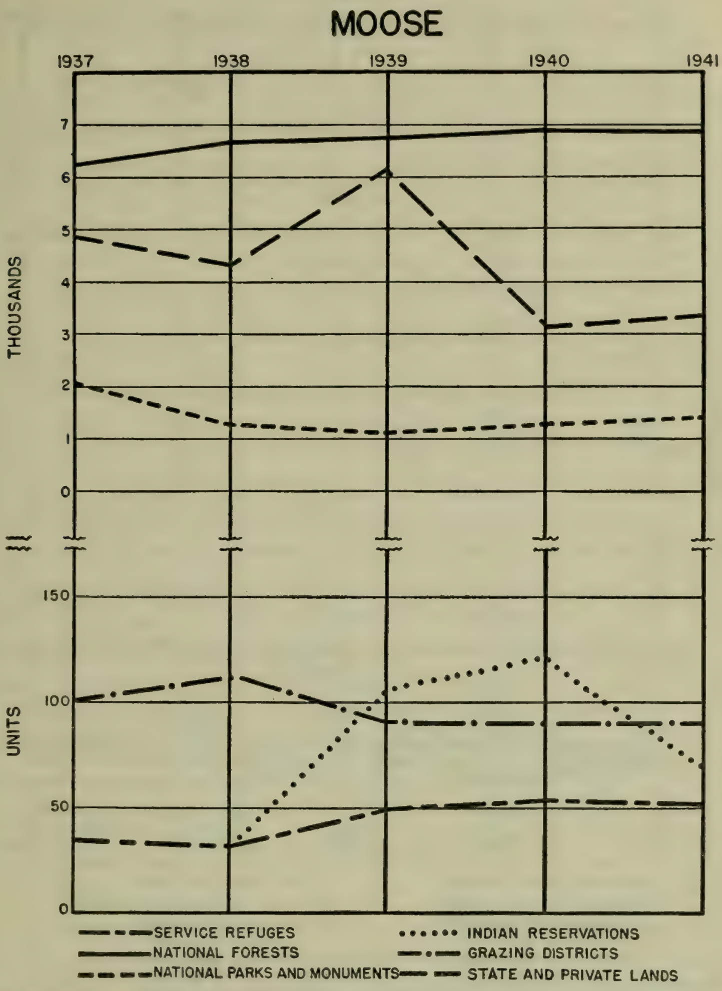
[7] Wildlife conditions in national parks, 1939. U. S. Dept. Int. Conserv. Bul. 3, 38 pp., illus. [1940.] [Processed.]

Moose

Although the moose now occurs in practically all the States it occupied in colonial times, its actual distributional area has shrunk to about a third of its former range. The numbers as indicated in the estimates (table 18) have shown a tendency to fluctuate from year



IGURE 9.—Populations of moose on different land-classification areas, 1937 to 1941.

) year. Consistent yearly increases for the 5-year period (1937–941) are apparent in the Montana estimates, however, as well as on a naller scale in those for Wyoming. On the whole, the tendency of ne moose population is downward (figs. 9 and 10), largely owing to a great decrease in Minnesota. Probably not much can be done to remedy the situation. The moose is an animal of the wilds and is averse to human proximity. It dwells primarily in wooded muskeg and lake regions, where it feeds extensively on aquatic and semiaquatic vegetation. When muskegs are drained and lake shores are lined with summer cottages, the moose habitat is destroyed.

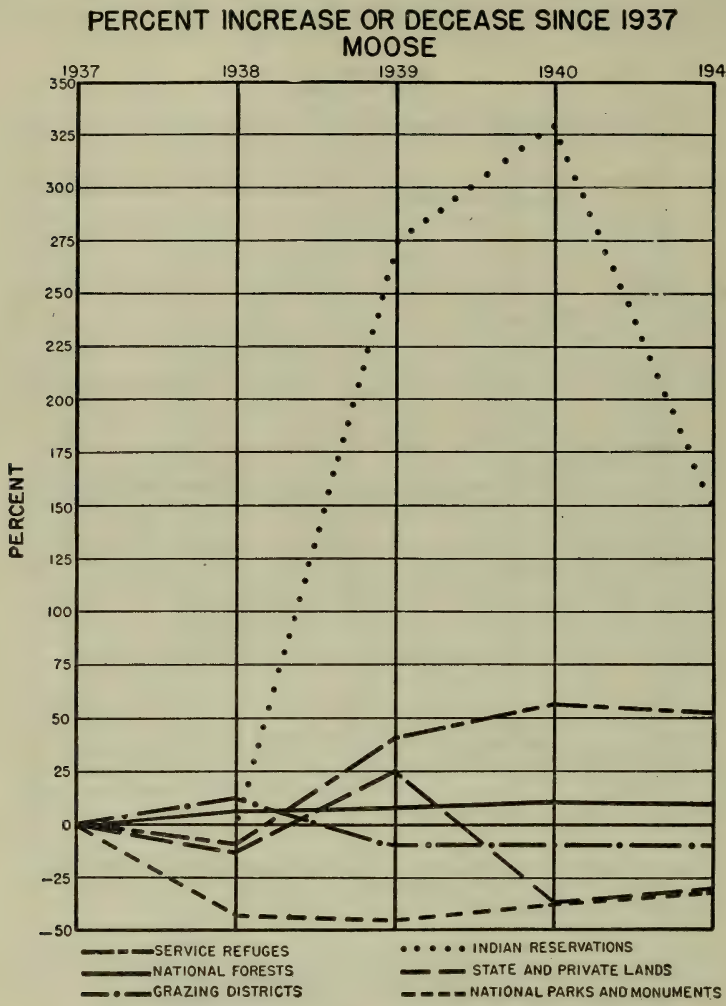


FIGURE 10.—Percentage increase or decrease, 1937 to 1941, in numbers of moose on different land-classification areas. In the case of Indian reservations, the population in 1938 is considered the base, as no observations were made in 1937.

TABLE 18.—*Estimated numbers of moose for the 5 leading States, 1937 to 1941*

State	1937	1938	1939	1940	1941
Idaho	887	845	785	900	1, 109
Maine	1, 839	1, 671	1, 842	2, 103	2, 283
Minnesota	4, 018	3, 649	5, 193	2, 039	1, 390
Montana	2, 187	2, 508	2, 567	2, 800	3, 065
Wyoming	3, 360	3, 439	3, 525	3, 500	3, 650

Prong-horned Antelope

The prong-horned antelope, originally found in 20 States west of the Mississippi River, still is resident in all of them except Kansas, where it was once abundant, and Minnesota, Iowa, and Missouri, where, occurrence, if actual, was very sparing and only on their western borders. The distribution of the species has dwindled to less than 5 percent of its former range, and its numbers to less than 1 percent of those on the plains a hundred years ago. The species seemed headed for extermination (Nelson, 1925) when, in 1927, "as a culmination of the efforts of wildlife conservationists, originated by the U. S. Biological Survey and extending over a period of several years, a definite step" was taken "to preserve the remnant of prong-horned antelopes of the Nevada-Oregon region" (Jackson, 1928). This step consisted of the taking over by the National Association of Audubon Societies from the Hapgood Brothers of the Last Chance Ranch in northwestern Nevada. In 1931, with an enlarged acreage, this became the Federal refuge now known as the Sheldon National Antelope Refuge. In 1936 additional protection was given by establishment of the adjoining Charles Sheldon Antelope Range to the east and south and of the Hart Mountain National Antelope Refuge to the north in Oregon. State organizations also have taken an active interest in conserving the pronghorn. Estimates for the 7 States at present leading in antelope populations are given in table 19, for the years 1922–24 (Nelson, 1925), 1937 [8], and 1941. The status of the antelope from 1937 to 1941 is indicated in two graphs (figs. 11 and 12).

TABLE 19.—*Comparison of the numbers of antelopes in 7 States in 1922–24, in 1937, and in 1941*

State	1922–24	1937	1941	State	1922–24	1937	1941
California	1, 057	12, 829	15, 256	New Mexico	1, 682	15, 022	30, 335
daho	1, 485	11, 867	17, 160	Oregon	2, 039	18, 484	26, 500
Montana	3, 027	10, 602	23, 537	Wyoming	6, 977	24, 386	24, 057
Nevada	4, 253	12, 700	21, 455				

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[8] See footnote 4, p. 3.

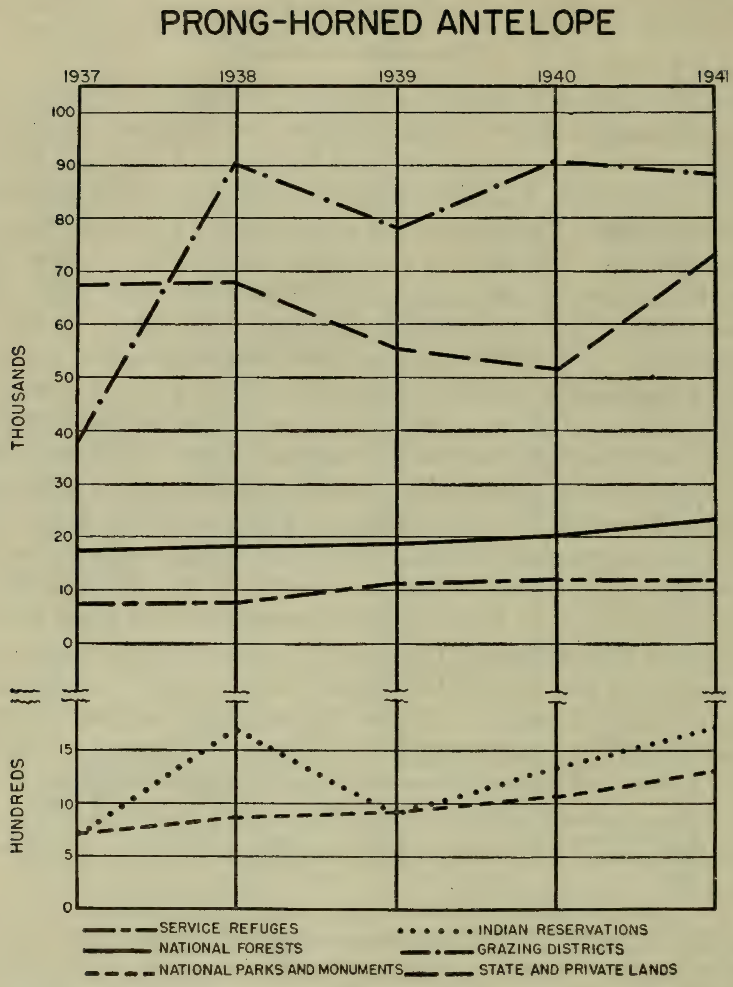


FIGURE 11.—Populations of prong-horned antelopes on different land-classification areas, 1937 to 1941.

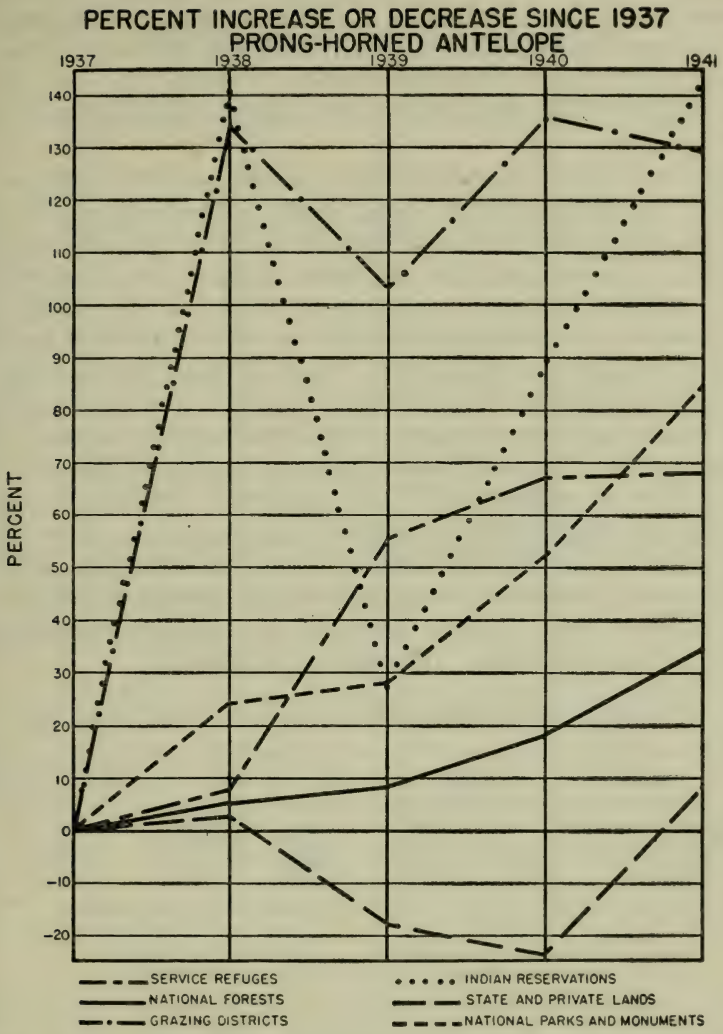


FIGURE 12.—Percentage increase or decrease, 1937 to 1941, in numbers of prong-horned antelopes on the different land-classification areas. The high in 1938 and the low in 1939 for Indian reservations probably are both traceable to erroneous estimates.

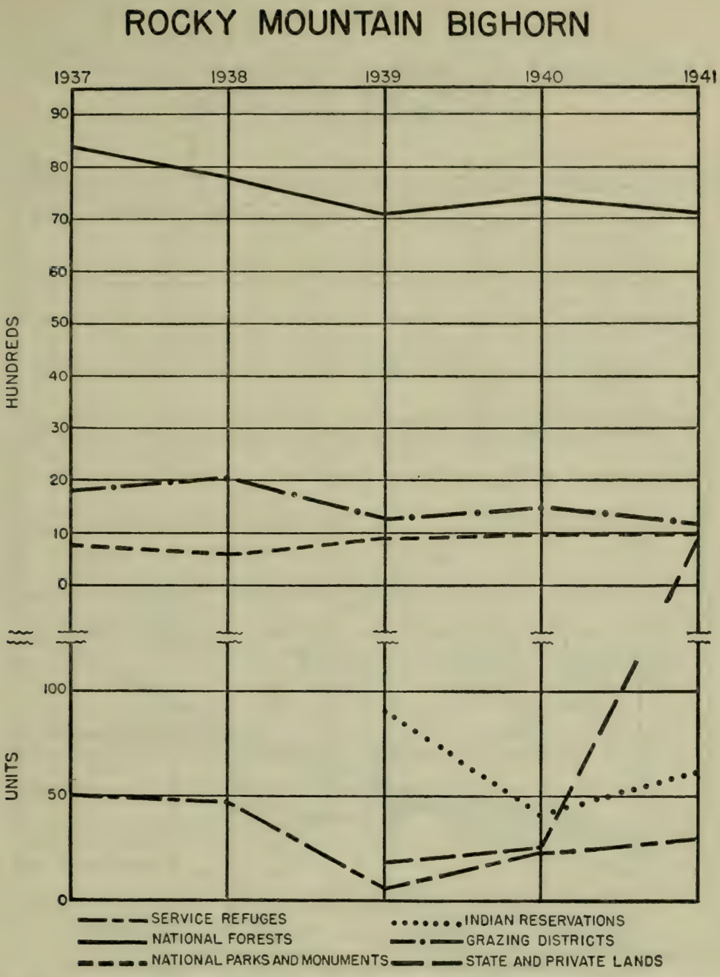
Bighorn Sheep

The range of the bighorn sheep at one time included most if not all of the mountains and buttes west of the 100th meridian except those near the Pacific coast in Washington, Oregon, and California. The species has been extirpated in North Dakota and Nebraska, and was extirpated (Audubon's bighorn) in South Dakota but has been reintroduced (Rocky Mountain bighorn), where there are now 25 bighorn sheep in the Black Hills. It has all but vanished from Oregon and Washington.

For making the annual estimates (table 20), the bighorns were divided into two groups, the Rocky Mountain bighorn and the desert bighorn, partly for the convenience of the investigations and partly because it was believed that the desert animals, the more southerly forms, might be in a more precarious condition than the Rocky Mountain animals. In the Rocky Mountain group are included the Rocky Mountain bighorn proper, and the Sierra Nevada, the Badlands, and the rimrock bighorns. The Badlands animal is now extinct, as probably is also the rimrock sheep. The desert bighorns found in the United States include the Nelson, Arizona, Texas, and Mexican forms. All of these are subspecies of *Ovis canadensis*. Bighorns in general are near the danger point, but good reports continue to be received with respect to the Tarryall herd of 500 on the Pike National Forest in Colorado. From the meagerness of its existing population and its inability to meet adverse conditions, the desert bighorn is in the most precarious situation. (See figs. 13, 14, and 15.)

TABLE 20.—*Estimated populations of bighorns in the United States, 1937 to 1941*

Species	1937	1938	1939	1940	1941
Rocky Mountain bighorn	10, 933	11, 367	9, 358	10, 016	10, 168
Desert bighorn	7, 020	5, 226	5, 341	4, 493	5, 157
All bighorns	17, 953	16, 593	14, 699	14, 509	15, 325



'IGURE 13.—Populations of Rocky Mountain bighorns on different land-classification areas, 1937 to 1941. The sharp rise in numbers on State and private lands in 1941 may be explained by a shift in populations from other land areas, the total number of Rocky Mountain bighorns in 1941 showing an increase of only 152 animals over that for 1940.

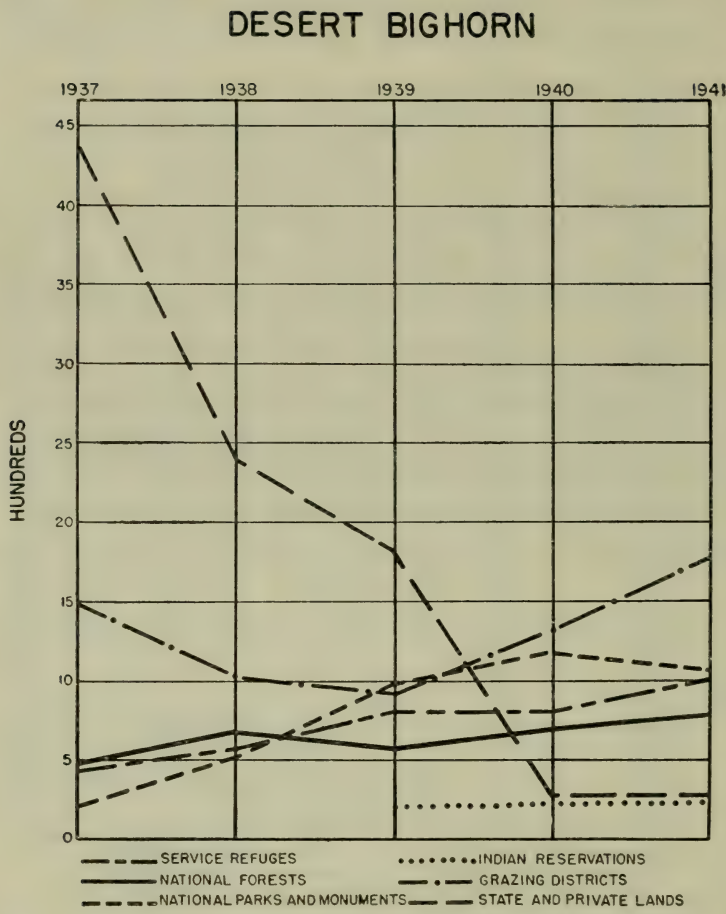


FIGURE 14.—Populations of desert bighorns on different land-classification areas, 1937 to 1941.

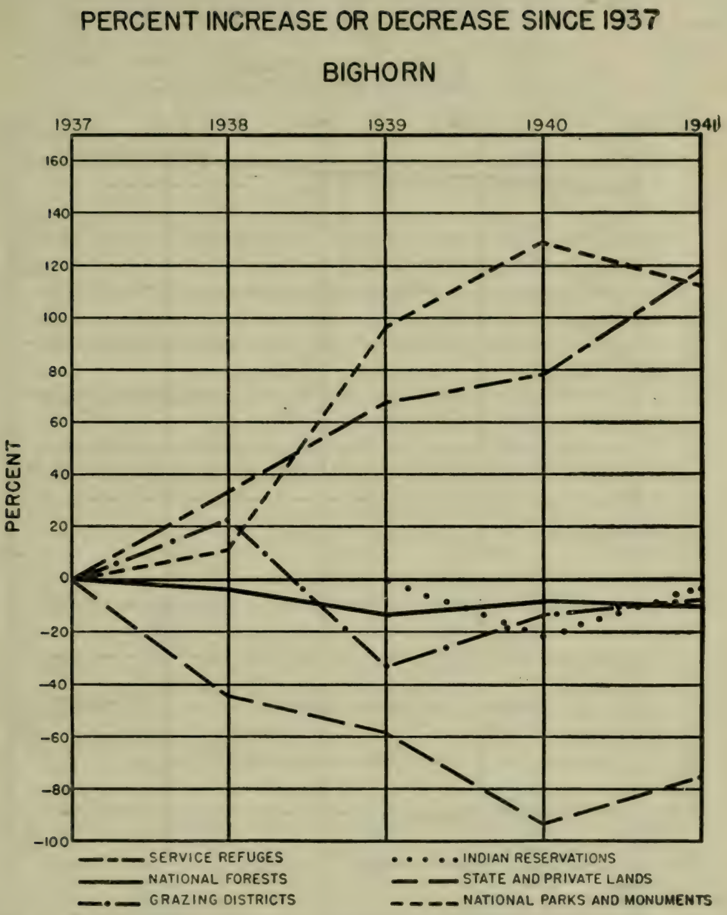


FIGURE 15.—Percentage increase or decrease, 1937 to 1941, in numbers of bighorns on different land-classification areas.

Mountain Goat

The mountain goat still occurs in the parts of the 3 States that were included in its recent ancestral range, namely, west-central Washington, northeastern and north-central Idaho, and western Montana. It was introduced, where it did not occur originally, into the Olympic Mountains, Wash., and into South Dakota, where a few individuals survive. The species as a food, fur, and hide producer is not suffi-

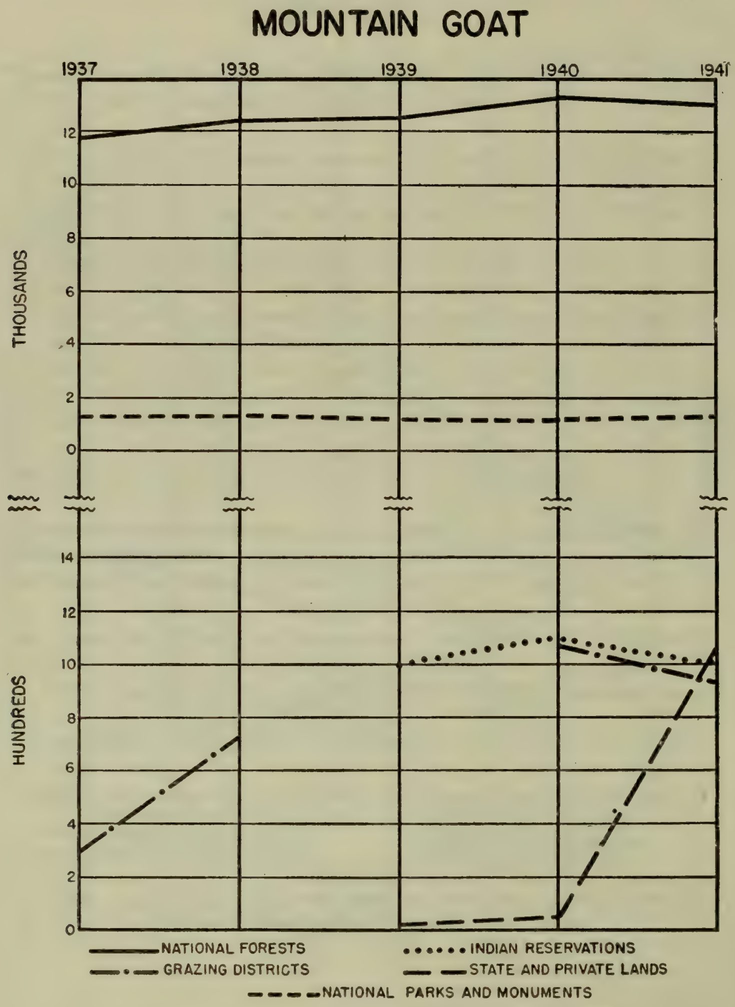


FIGURE 16.—Populations of mountain goats on different land-classification areas, 1937 to 1941. The increases indicated for State and private lands may be accounted for by the transfer of lands or the transplanting or shifting of animals, as no such increase in the total number of mountain goats is shown for that period.

ciently abundant to be an important big-game animal. As an interesting mammal, attractive as a trophy, and providing excellent sport and recreation for hunting, it ranks high. Its numbers are being maintained, and estimates of them show on the whole a rather consistent annual increase (figs. 16 and 17).

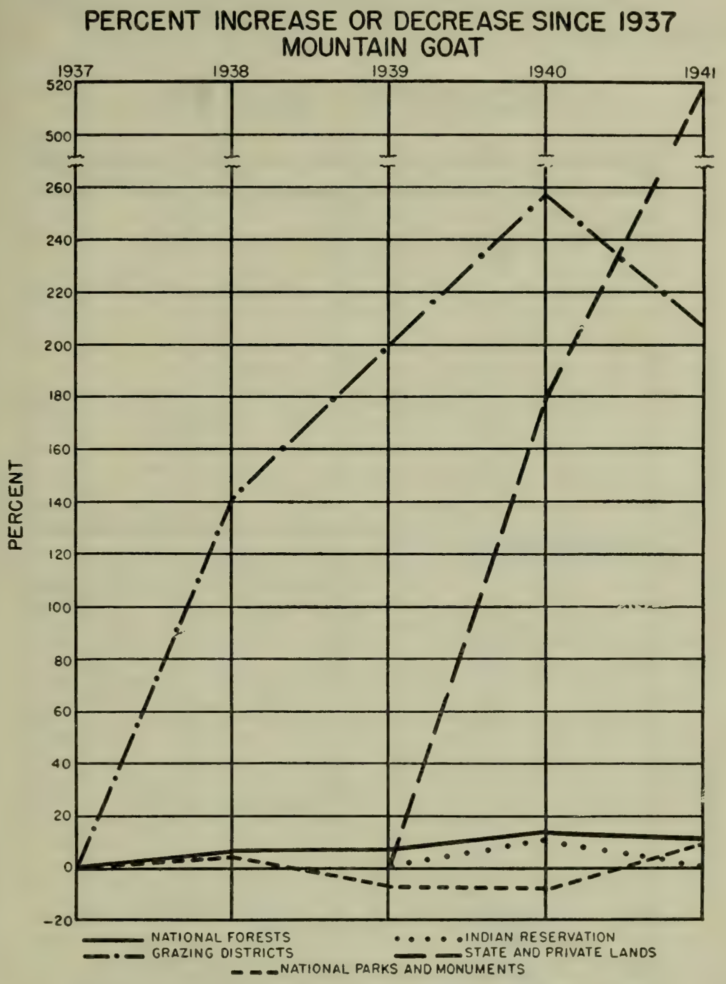


Figure 17.—Percentage increase or decrease, 1937 to 1941, in numbers of mountain goats on different land-classification areas. The excessive increases shown for grazing districts and State and private lands may be due to low estimates in the earlier years, but more probably to transfer of lands or shift of populations. No such increase is shown in the total number of mountain goats.

Collared Peccary

The collared peccary, or javelina, which once inhabited in droves most of the brush area of central and southern Texas, southern New Mexico, and southeastern Arizona, is now greatly reduced in numbers and restricted in distribution, although still found in all of these States. It has shown a yearly increase in numbers from 1938 to 1941 (figs. 18 and 19).

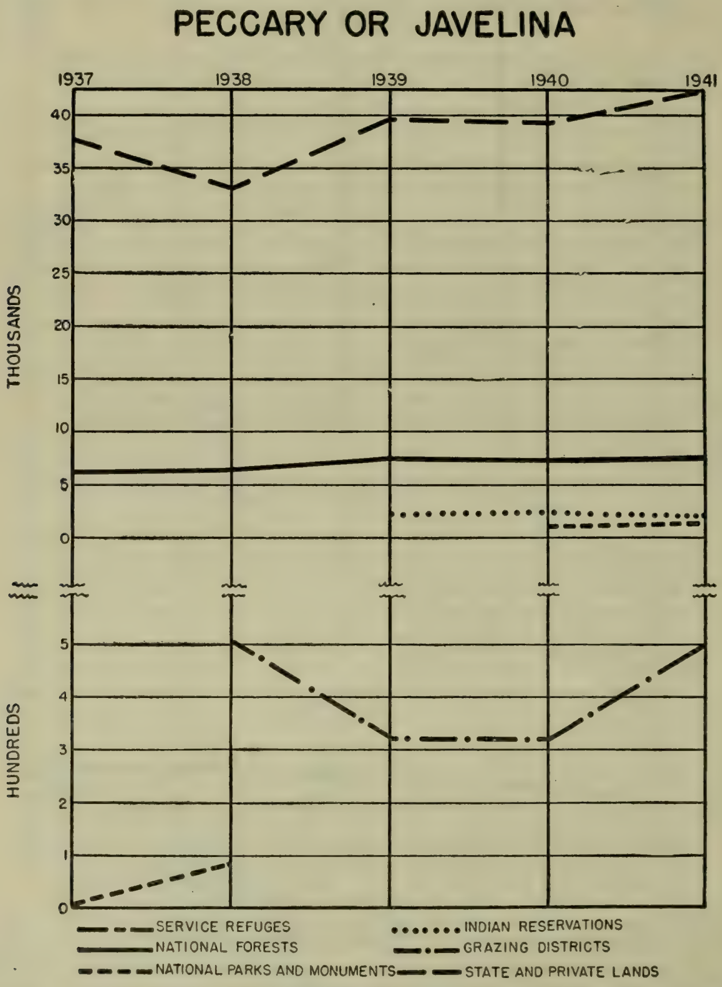


FIGURE 18.—Populations of peccaries, or javelinas, on different land-classification areas, 1937 to 1941. Population of 200 on Service Refuges from 1938 to 1941 not shown on graph.

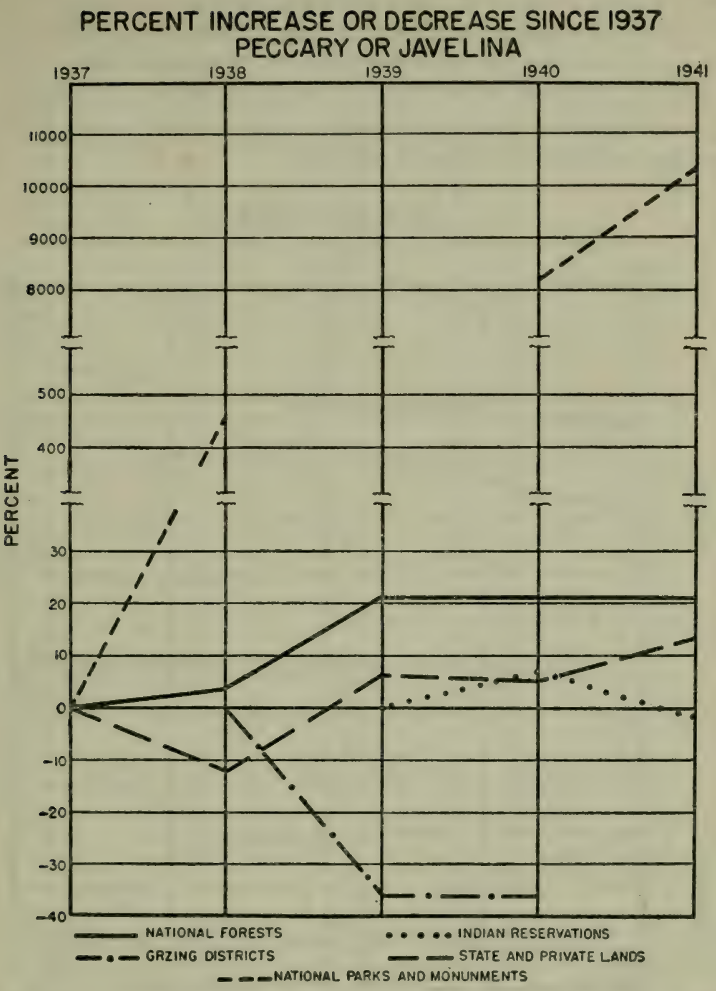


Figure 19.—Percentage increase or decrease, 1937 to 1941, in numbers of peccaries, or javelinas, on different land-classification areas. The high increase in peccaries on national parks and monuments is accounted for largely by the discovery of larger herds on the Organ Pipe Cactus National Monument, Ariz., and by the transfer of the count of some animals from grazing districts to national parks and monuments.

Black Bear

The black bear is the only American big-game species that originally occurred in every State, though absent from Nevada in all except the extreme western part and from large parts of western Arizona, southern California, and southeastern Oregon. It has vanished from most of its former range, yet still occurs in 32 of the 48 States. It is increasing in numbers over the country as a whole, and is the only species of big game that has shown an increase each year during the 5-year period, 1937–41 (figs. 20 and 21).

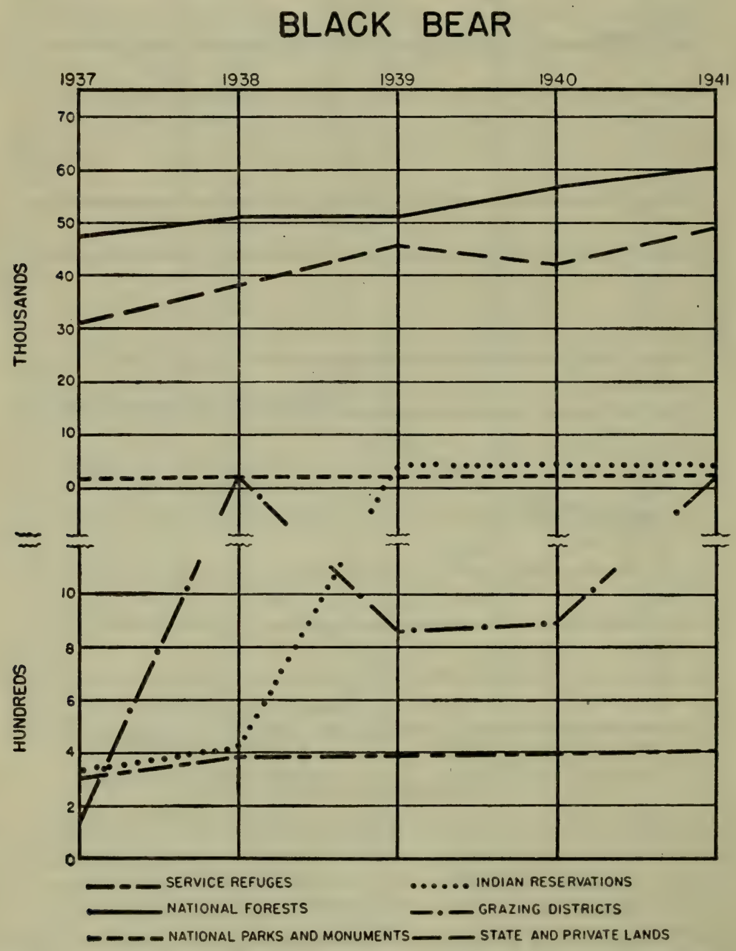
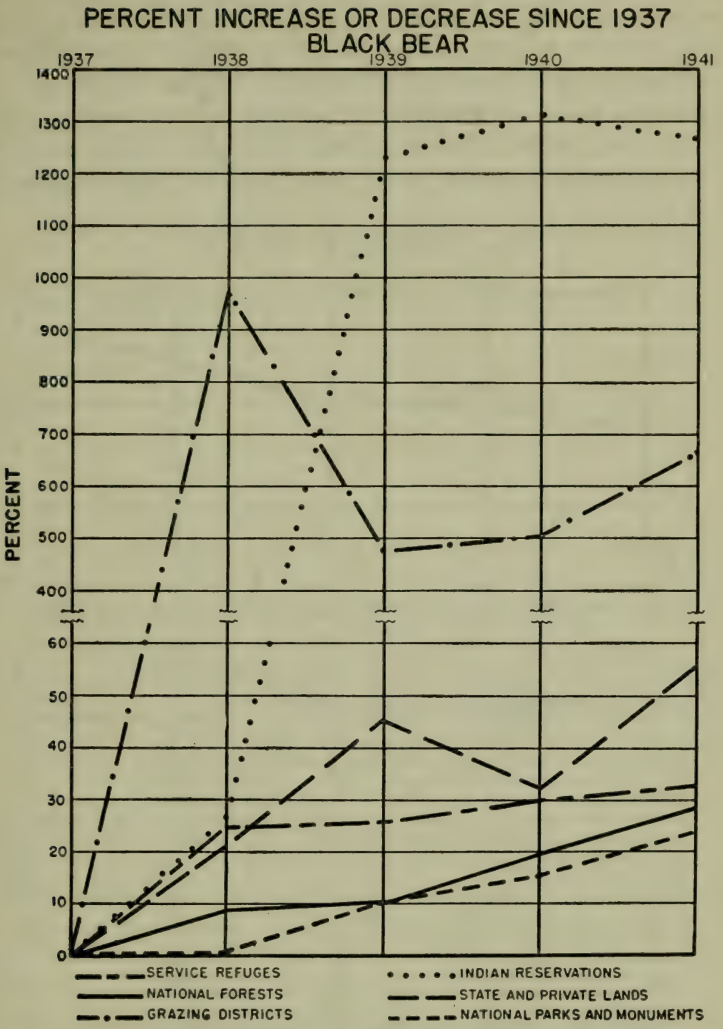


FIGURE 20.—Populations of black bears on different land-classification areas 1937 to 1941.



GURE 21.—Percentage increase or decrease, 1937 to 1941, in numbers of black bears on different land-classification areas. The striking rise in the estimates for Indian reservations is accounted for by the lack of information until 1939 concerning the numbers of black bears on these lands.

Grizzly Bear

Grizzly bears at the time of early exploration were found in the 1 States from North and South Dakota, Nebraska, and Texas to th Pacific coast. In 1941 they occurred in only 6 States, in 3 of whic they were practically extirpated, in one (Idaho) with such a low population as to be in danger, and in only two (Montana and Wyoming in any considerable numbers. According to the estimates, grizzl bears have shown an appreciable increase since 1937, with a slight decrease in 1941, however, as compared with 1940 (figs. 22 and 23 They had decreased steadily until about 1935 and had vanished fro

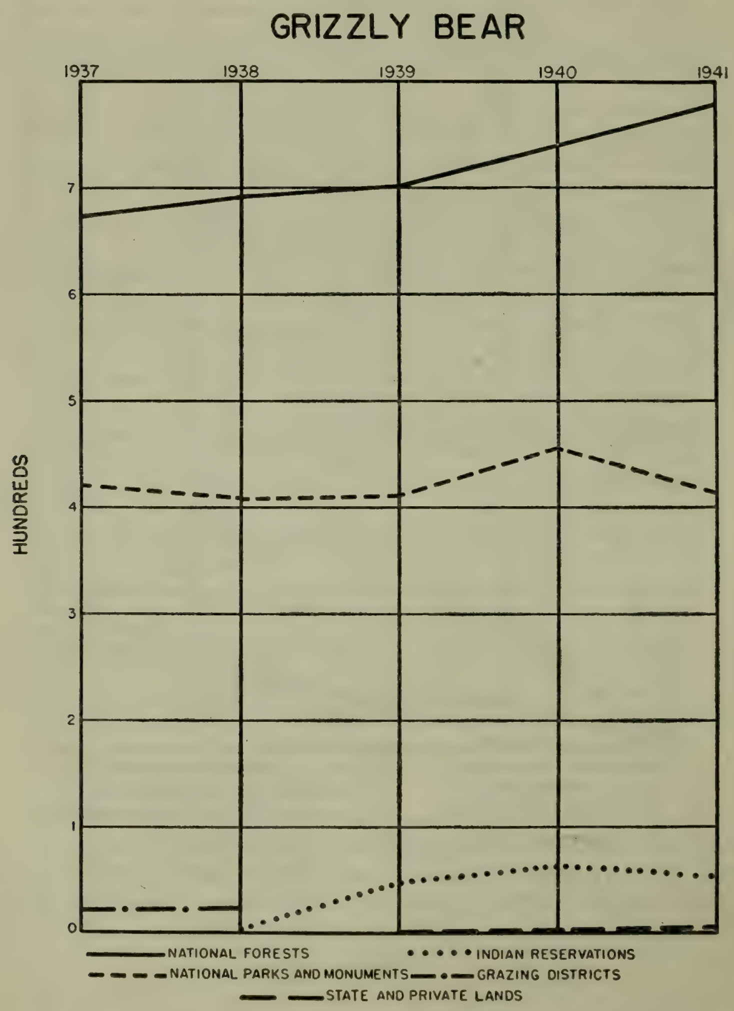
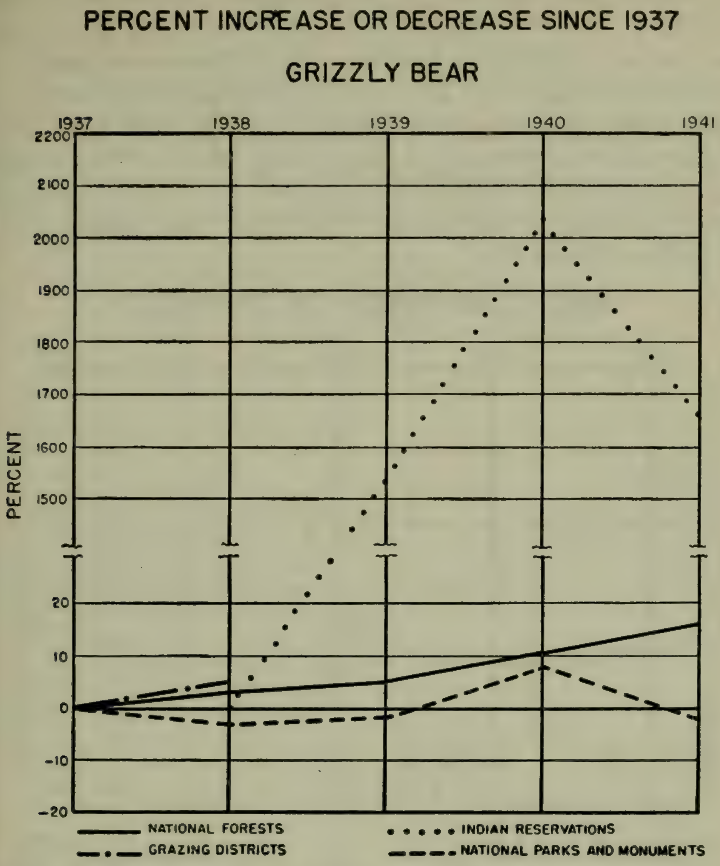


Figure 22.—Populations of grizzly bears on different land-classification areas 1937 to 1941.

any regions in the period between 1920 and 1935. They must still considered endangered.



URE 23.—Percentage increase or decrease, 1937 to 1941, in numbers of grizzly ears on different land-classification areas. The abrupt rise, 1938 to 1940, n Indian reservations is occasioned by too low estimates in the earlier years.

American Bison, or Buffalo

The number of bison in the United States at the time of its earlier tlements has been variously estimated. Fifty million would be a servative figure. By 1870 the number had been reduced to less n 6,000,000 animals occupying a comparatively narrow strip of ins from central Texas, western Oklahoma and Kansas, and eastern lorado northwesterly through the western half of the Dakotas and st of Wyoming and Montana to the Canadian border. The low in buffalo population in the United States appeared to be in 1889, en, according to Hornaday's estimate, there were 541 of these animals in this country. Through the efforts of the American Biso Society, the Fish and Wildlife Service, and various other Federal State, and private organizations, the number of bison in the Unite States today is about 5,200 (table 21), of which 4,980 are mainly o fenced ranges controlled by Federal or State Governments or by pri vate individuals, and some 220 in city parks, zoological gardens, cir cuses, and other limited areas. With a herd of more than 200, th offspring of introduced stock, in Alaska, and some 15,000 in Canada, i would appear that the American bison has withdrawn from the brin of destruction that threatened it. The trend from 1937 to 1941 wa upward (figs. 24 and 25).

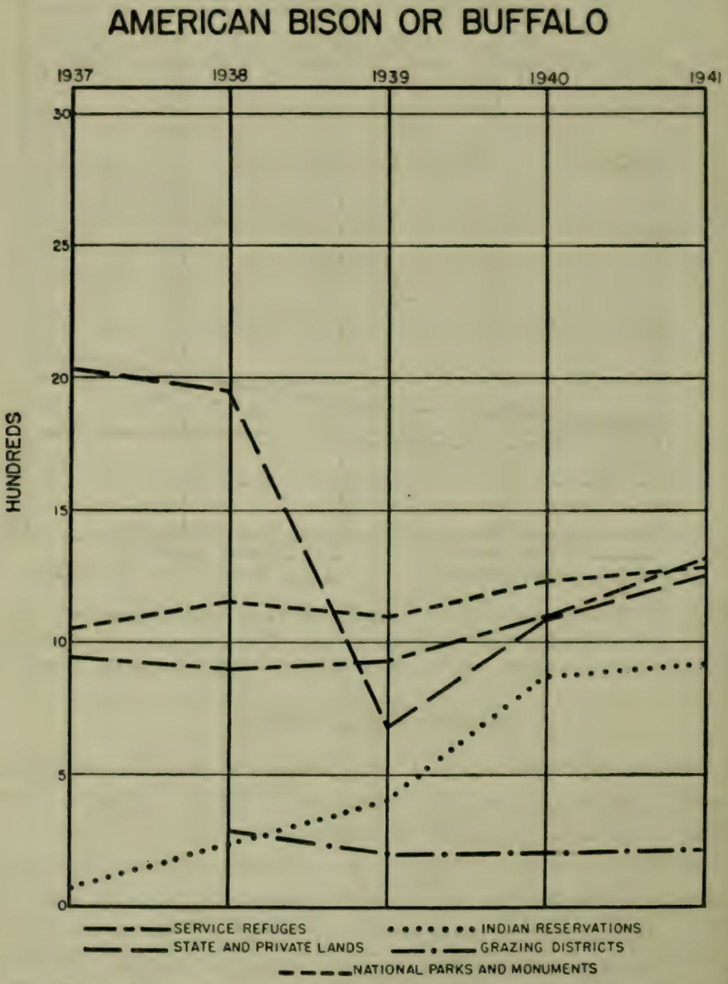


FIGURE 24.—Populations of American bison, or buffaloes, on different land-class fication areas, 1937 to 1941. The drop in 1939 estimates for State and privat lands results from buffaloes in city parks and zoological gardens not bein counted after 1938.

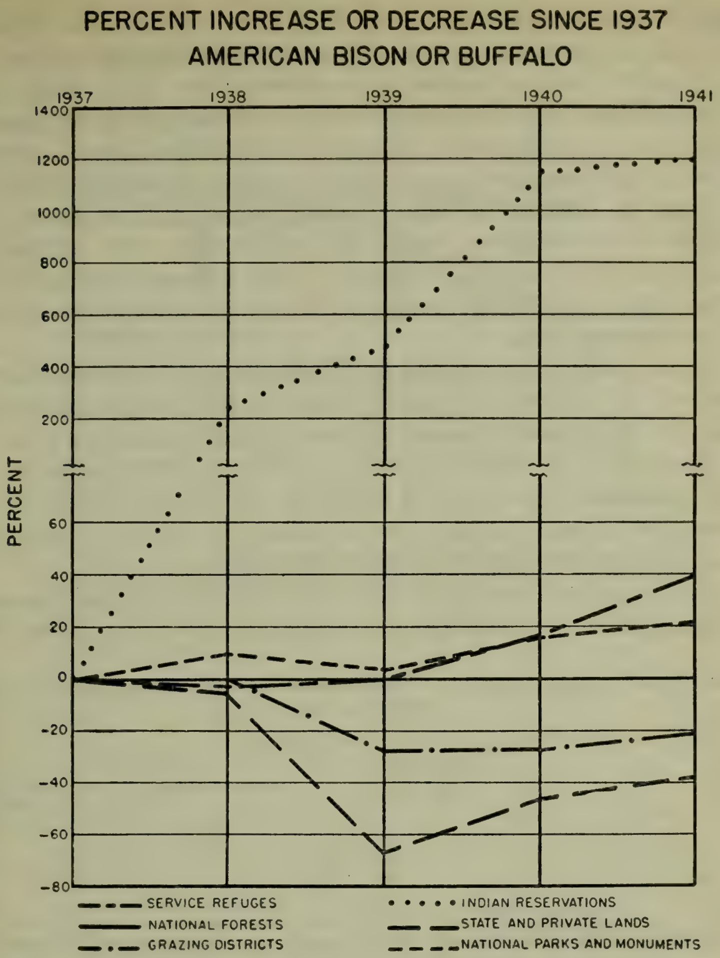


FIGURE 25.—Percentage increase or decrease, 1937 to 1941, in numbers of American bison on different land-classification areas. The rise in the numbers shown for Indian reservations is mainly due to introductions on the Crow Indian Reservation, Mont., and to natural increase in the herd there.

TABLE 21.—*Estimated total numbers of American bison in the United States*

Year	Number of bison	Year	Number of bison
70	5, 500, 000	1933	4, 404
89	541	1941	5, 200
05	800		

Introduced Species

As a general rule, the introduction of exotic mammals for game use to replace native species is not a judicious policy. Of all exotic big-game species introduced into the United States, the European wild boar has probably become the most important and is the only one of which annual population estimates have been made. The species was first introduced into the United States as a game animal in 1912 (Stegeman, 1938: 280). In some of the Southern States it readily bred with feral domestic pigs, so that in some regions pure-strain wild boars may be difficult to find. Possibly some of these hybrids are included in the estimates (table 22). More than half of the 1,232 animals found in the United States in 1941 were on national forests, and the largest established colony was of 500 animals on the Cherokee National Forest, Tenn.

On State and private lands in Kentucky in 1941 there were 815 European red deer, the only herd of considerable size in this country. These deer have been the cause of some trouble on account of conflict with domestic stock. While excellent of flesh, the European red deer as big game does not equal the American elk in food, hide, or sport qualities, or in size, and appears to be inferior in every way to the American elk as a big-game animal for America.

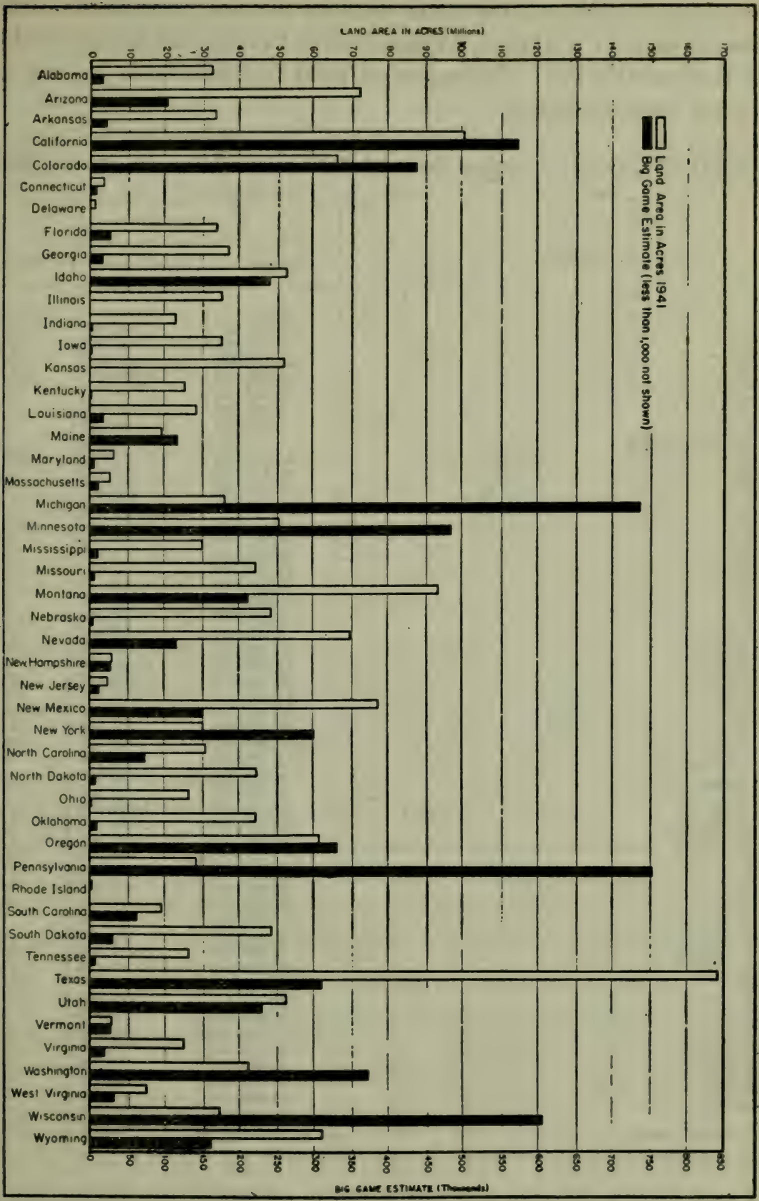
There are about 125 fallow deer on State and private lands in Alabama, and a few have been introduced into southern Florida.

TABLE 22.—*Estimated numbers of European wild boars in the United States, 1937 to 1941*

Year	Number of European wild boars	Year	Number of European wild boars
1937	725	1940	1, 390
1938	845	1941	1, 232
1939	1, 650		

POPULATION TRENDS IN BIG GAME ON DIFFERENT LAND-CLASSIFICATION AREAS

Figures covering the total land and water areas of the States, counties, cities, and minor civil divisions, and representing the first basic remeasurement of the United States since 1880, have been published by the Bureau of the Census, of the United States Department of Commerce (Batschelet and Proudfoot, 1942). The figures therein are given in square miles. For present use, those in the tabulation of areas by States (Batschelet and Proudfoot, 1942: 6) have been converted into acres and appear in table 23. In making wildlife-population statements, the best way to indicate density of population is through number of animals per unit area. The unit area that is becoming more or less standard is 100 acres. In the chart (fig. 26) showing land areas in acres and big-game estimates by States for 1941, it was necessary to designate *millions* of acres and *thousands* of



IGURE 26.—Land area of States in millions of acres and big-game estimates in thousands for the year 1941. Shortening the black block one-half will indicate the number of animals per 100-acre unit in each State.

animals in order to adjust figures to the chart. Shortening the black blocks one-half will picture the number of animals per 100-acre unit The relative number of big-game animals per unit area in the different States is seen at a glance, Pennsylvania having the high population and Kansas the low. Acreages of land not habitable by big game have not been deducted.

TABLE 23.—*Land and water areas of the United States, by States: 1940*

State	Area		
	Land	Inland water	Total
	Acres	*Acres*	*Acres*
Alabama	32, 689, 920	339, 840	33, 029, 760
Arizona	72, 691, 200	210, 560	72, 901, 760
Arkansas	33, 744, 000	241, 280	33, 985, 280
California	100, 353, 920	1, 209, 600	101, 563, 520
Colorado	66, 538, 880	179, 200	66, 718, 080
Connecticut	3, 135, 360	70, 400	3, 205, 760
Delaware	1, 265, 920	50, 560	1, 316, 480
District of Columbia	39, 040	5, 120	44, 160
Florida	34, 727, 680	2, 750, 720	37, 478, 400
Georgia	37, 451, 520	229, 120	37, 680, 640
Idaho	52, 997, 120	479, 360	53, 476, 480
Illinois	35, 806, 080	289, 920	36, 096, 000
Indiana	23, 171, 200	55, 040	23, 226, 240
Iowa	35, 831, 040	188, 160	36, 019, 200
Kansas	52, 552, 320	104, 320	52, 656, 640
Kentucky	25, 669, 760	183, 040	25, 852, 800
Louisiana	28, 913, 280	2, 141, 440	31, 054, 720
Maine	19, 865, 600	1, 392, 000	21, 257, 600
Maryland	6, 327, 680	441, 600	6, 769, 280
Massachusetts	5, 060, 480	224, 000	5, 284, 480
Michigan	36, 494, 080	764, 160	37, 258, 240
Minnesota	51, 205, 760	2, 597, 760	53, 803, 520
Mississippi	30, 348, 800	189, 440	30, 538, 240
Missouri	44, 332, 800	258, 560	44, 591, 360
Montana	93, 642, 240	526, 080	94, 168, 320
Nebraska	49, 057, 920	373, 760	49, 431, 680
Nevada	70, 273, 280	472, 320	70, 745, 600
New Hampshire	5, 775, 360	179, 200	5, 954, 560
New Jersey	4, 814, 080	200, 960	5, 015, 040
New Mexico	77, 767, 040	99, 200	77, 866, 240
New York	30, 674, 560	1, 054, 080	31, 728, 640
North Carolina	31, 450, 880	2, 284, 800	33, 735, 680
North Dakota	44, 834, 560	391, 040	45, 225, 600
Ohio	26, 318, 080	64, 000	26, 382, 080
Oklahoma	44, 341, 120	407, 040	44, 748, 160
Oregon	61, 664, 000	403, 850	62, 067, 840
Pennsylvania	28, 828, 800	184, 320	29, 013, 120
Rhode Island	677, 120	99, 840	776, 960
South Carolina	19, 580, 160	295, 040	19, 875, 200
South Dakota	48, 983, 040	327, 040	49, 310, 080
Tennessee	26, 855, 040	182, 400	27, 037, 440
Texas	168, 732, 160	2, 364, 800	171, 096, 960
Utah	52, 701, 440	1, 644, 800	54, 346, 240
Vermont	5, 937, 920	211, 840	6, 149, 760
Virginia	25, 535, 360	586, 240	26, 121, 600
Washington	42, 865, 280	777, 600	43, 642, 880
West Virginia	15, 417, 600	58, 240	15, 475, 840
Wisconsin	35, 017, 600	920, 960	35, 938, 560
Wyoming	62, 403, 840	261, 120	62, 664, 960
United States	1, 905, 361, 920	28, 965, 760	1, 934, 327, 680

Land area habitable for big game is estimated by deducting from the land and water areas under national control 1½ percent of the acreage to allow for inland water, this percentage being approximate for the entire United States. Total acreages for areas under national control were taken from fiscal year 1941 reports of the individual agencies when possible. Land area habitable for big game on State and private lands is estimated by deducting from the total United States land area (1,905,361,920 acres) the sum of United States Government controlled land (361,979,747 acres) plus an estimate (592,000,000 acres) of land including urban (50,000,000 acres), farm crops (400,000,000 acres), and some of the farm pasture lands (142,000,000 acres), the remainder being some 951,382,173 acres. The areas available for big game in the United States would thus fall into the classification presented in table 24.

TABLE 24.—*Land and water acreage by ownership or control, excluding urban and intensively farmed areas*

Ownership or control	Area		
	Land	Inland water	Total
	Acres	*Acres*	*Acres*
Fish and Wildlife Service refuges	9, 448, 822	143, 891	9, 592, 713
National forests	143, 810, 000	2, 190, 000	146, 000, 000
National parks and monuments	15, 392, 881	234, 409	15, 627, 290
Indian reservations	50, 627, 942	770, 984	51, 398, 926
Grazing districts	142, 700, 102	2, 173, 098	144, 873, 200
State and private lands (habitable by big game)	951, 382, 173	14, 488, 053	965, 870, 226

Changes in Big-Game Populations of States, 1940–41

Human population and its distribution, as well as its character and hunting tendencies, are factors important in relation to the management of big game. In fact, distribution in a broad sense is a major feature of big-game management. Distribution of range food plants, distribution of game animals on winter range, distribution of introduced animals to unstocked game lands, distribution of hunters, and distribution of the commodity after the kill are all important factors in big-game production and utilization. The chart (fig. 27) showing a comparison of human population with big-game population as of December 31, 1940, in the 20 States leading in big-game numbers exhibits interesting contrasts. New York, for example, which ranked first in human population and ninth in big-game population, had 1 big-game animal to every 54 people. Nevada, lowest in human population of the 20 States and eighteenth in big-game population, had approximately 7 big-game animals to 10 people. Wyoming, another State of low human population, had 11 big-game animals to 20 people.

The unusual increase of 13.1 percent in all big game in the United States in 1941 over the number estimated the previous year was probably caused by exceptionally favorable weather and food conditions during the 12 months or more preceding the 1941 estimate. The change becomes more illuminating on comparing the individual State changes, which run from a decrease of 49.7 percent in Kentucky to an increase of 125.8 percent in Washington. This striking gain for Washington may indicate an underestimate for 1940. Changes in the game populations can best be comprehended by a study of the map (fig. 28).

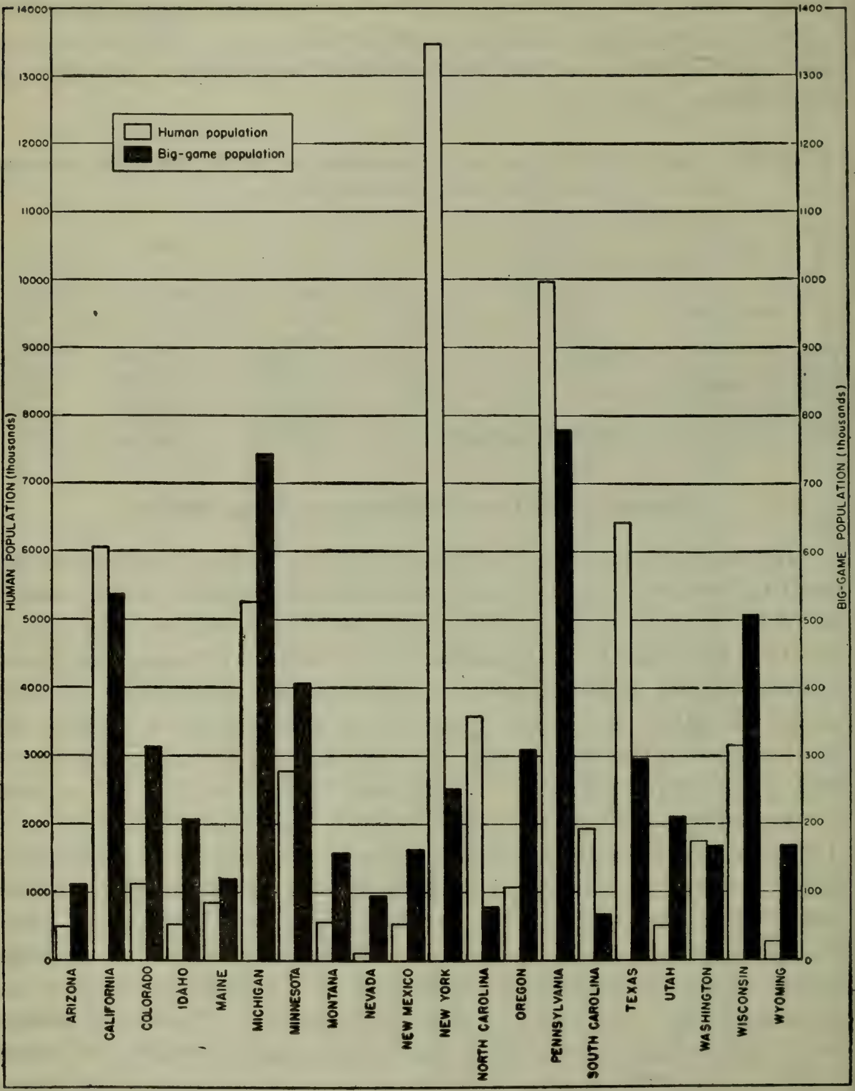


FIGURE 27.—Human, compared with big-game, populations in 20 States, 1940.

The Bureau of the Census has supplied information on percentage change from the results of the 1940 census in human population for each State as of April 30, 1942. The changes in human populations in the States (fig. 29), particularly during the war, are caused chiefly

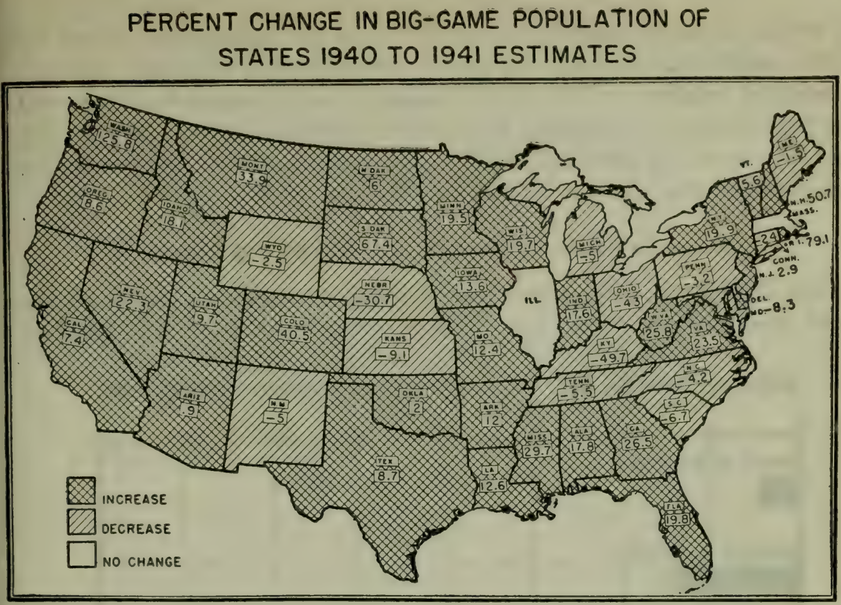

PERCENT CHANGE IN BIG-GAME POPULATION OF STATES 1940 TO 1941 ESTIMATES

FIGURE 28.—Percentage change in big-game populations of States, 1940 to 1941. Delaware had an increase of 19 deer by introduction, not shown as a percentage increase. The population changes are caused mainly by births and deaths.

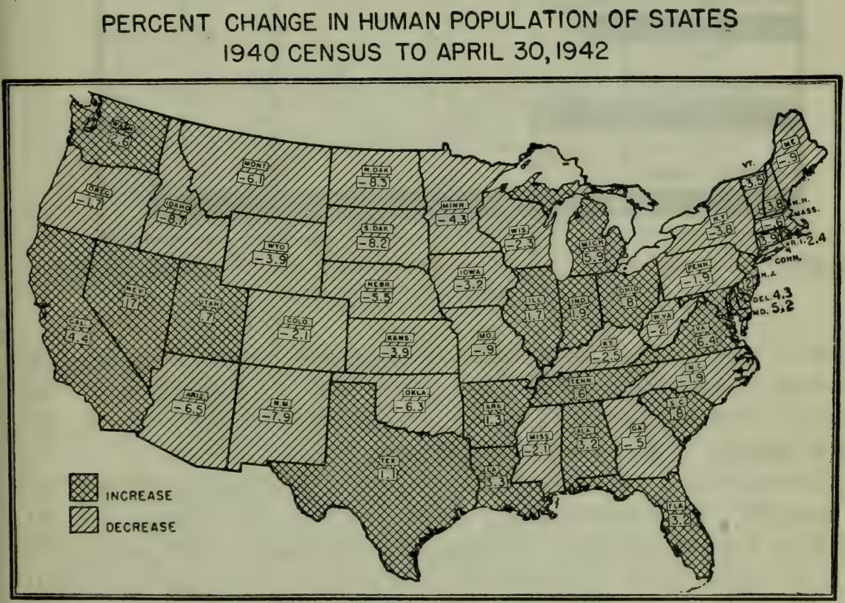

PERCENT CHANGE IN HUMAN POPULATION OF STATES 1940 CENSUS TO APRIL 30, 1942

FIGURE 29.—Percentage change in human population of States, 1940 to April 30, 1942, based on figures supplied by the Bureau of the Census, United States Department of Commerce. The changes are caused mainly by shifts in population.

by actual shifts of individuals, rather than by fluctuations caused by births and deaths, as with big game. Nevertheless, they may have an important relation to per capita demand for big-game hunting, and the possibilities of a change in relation between demand and supply may be somewhat predicated by a comparison of the changes in the two populations (compare fig. 28 and fig. 29).

Changes in Big-Game Populations on Land-Control Areas

Considering the huge numbers of big-game animals on some of the land-classification areas, particularly those for State and private lands, it would seem that the density of big-game population must be greatest there. More enlightening, however, is comparison of the density of populations as indicated by the number of animals per 100 acres (fig. 30) or by percentage increases.

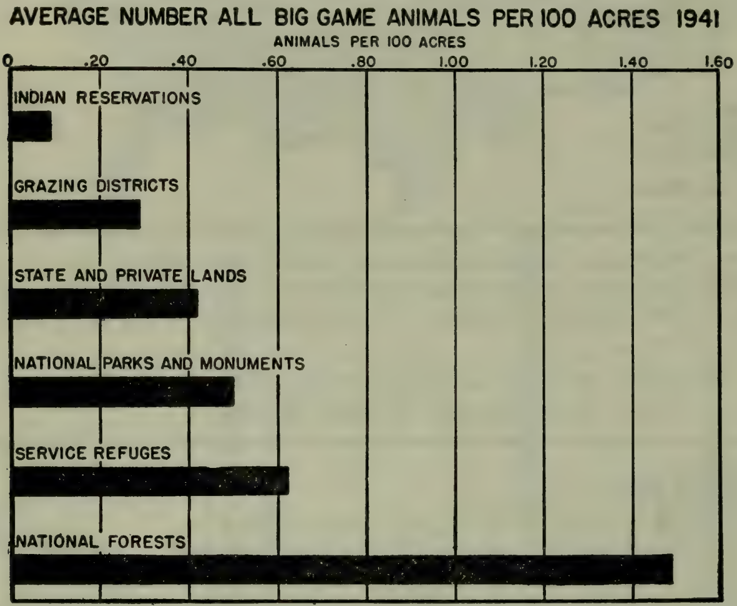
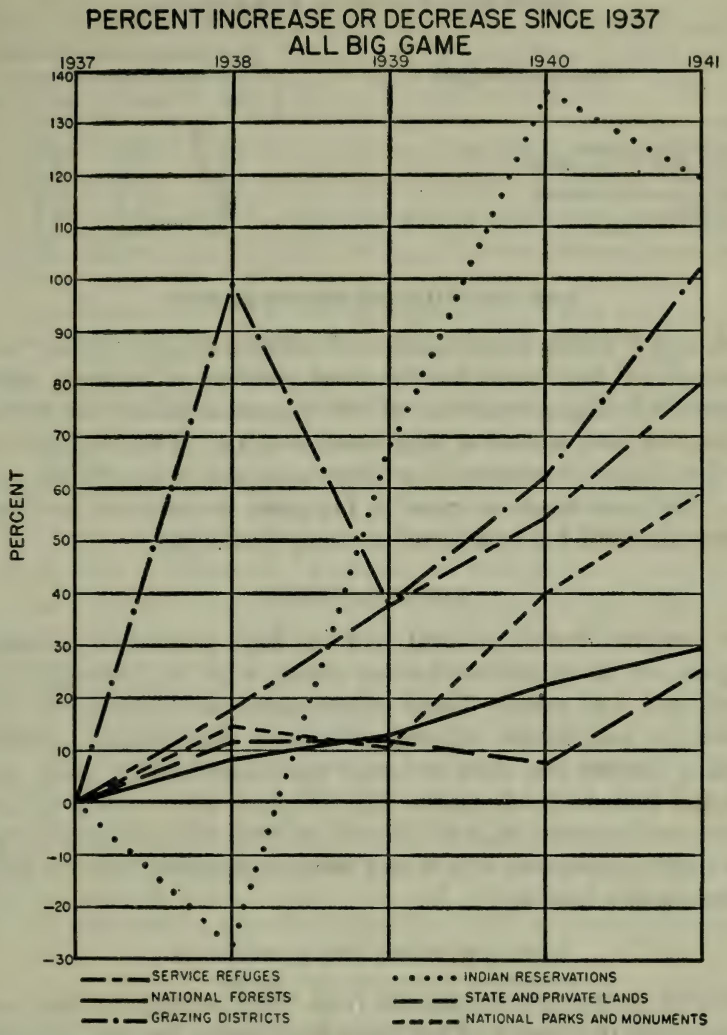


Figure 30.—Average number of all big-game animals per 100 acres in the different land-classification areas, 1941.

The chart (fig. 30) shows a population in 1941 ranging from 0.09 animal per 100 acres on Indian reservations to 1.49 animals per 100 acres on national forests. Increase in population in 1941 since 1937 (fig. 31) ranges from 25.3 percent on State and private lands to 119.0 percent on Indian reservations. The apparently high percentage increase on Indian reservations is doubtless due to low estimates made for 1937. The total percentage increase over 1937 in big-game popu-



IGURE 31.—Percentage increase or decrease, 1937 to 1941, in the numbers of all big-game animals on different land-classification areas. The high in grazing districts in 1938 was caused by an overestimate, which was later, although not sufficiently, reduced. Too low estimates in 1937, 1938, and probably in 1939 account for the apparently high percentage increase on Indian reservations in 1940.

lations in the United States on all land-classification areas is shown in table 25.

TABLE 25.—*Percentage increase over 1937 in big-game populations on land-classification areas in the United States*

Land-classification areas	Percentage increase over 1937			
	1938	1939	1940	1941
All land-classification areas	14.6	13.3	15.6	30.8
Fish and Wildlife Service refuges	18.1	37.6	54.8	80.7
National forests	8.2	12.9	22.6	29.7
National parks and monuments	14.6	10.5	39.8	59.5
Grazing districts	99.6	37.6	62.9	104.2
State and private lands	11.5	11.4	7.5	25.3

FISH AND WILDLIFE SERVICE REFUGES

Fish and Wildlife Service national wildlife refuges, which have a comparatively low figure for the total numbers of animals, show a comparatively high population of 0.62 big-game animal per 100 acres in 1941, and rank second in population density. This estimate is for areas that include considerable acreages managed primarily for waterfowl. The percentage increase in big-game animals on the Service refuges since 1937 has been notably steady (table 25).

NATIONAL FORESTS

The national forests in 1941 had the high population density in big game of all land-classification areas, with an average of 1.49 animals per 100 acres. These forest areas also showed a steady increase in population throughout the 5-year period (1937-41), though a smaller one than on other land-classification areas except State and private lands (table 25). This is as it should be under efficient management, since the forests in 1937 were already supporting a high population, which had been maintained but not greatly increased under hunting.

NATIONAL PARKS AND MONUMENTS

National parks and monuments rank third among the land-classification areas in density of big-game population, having an average of 0.50 per 100 acres. These lands have shown a tendency toward big game increase each year except 1939, when there was a slight drop (table 25).

GRAZING DISTRICTS

Grazing districts in 1941 indicated an average of 0.29 big-game animal per 100 acres. Except for the one year, 1938, big game on the grazing districts increased consistently (table 25). The original figures for 1938 were known to be excessive and were pared down considerably for the estimates. Even so they were probably too high.

INDIAN RESERVATIONS

Indian reservations ranked sixth, or lowest, of all land-classification areas in the average density of big-game population in 1941, with 0.09 animal per 100 acres. With few exceptions, there seems to be a greater average density of big game on lands adjoining the reservations, a difference in population that has been increasing for a decade or more. The percentage increases shown in the graph (fig. 31) do not, therefore, represent a true picture of the change in big-game populations on Indian lands. The estimates of populations on Indian lands for 1937 were made chiefly by the author from reports available in the Fish and Wildlife Service and were probably ultraconservative. Moreover, these estimates included only part of the big-game species, namely, white-tailed and mule deer, elk, pronghorned antelope, black bear, and buffalo. For the year 1938 an even more conservative estimate was made by others in the Service. In 1939, 1940, and 1941, more accurate and complete information was received. The drop in 1941 may be the result of inability to get reports from some of the Northwestern States that had reported in 1939 and 1940. Clifford C. Presnall, of this Service, formerly in charge of Wildlife on Indian Lands, summarized the situation on Indian reservations in a letter of March 24, 1943, as follows: "Big-game inventories reported from Indian reservations during the past 5 years are often not truly indicative of actual trends in population, owing to difficulties in obtaining complete data. Competent observers believe that desert bighorns, javelinas, and black bears have held their own or increased slightly. Antelopes and buffaloes have increased, the latter in marked degree. All species of deer, as well as grizzly bears and Rocky Mountain bighorns, have declined slowly during the past 5 years. The status of the moose and the elk is uncertain, although it appears likely that they are on the increase."

STATE AND PRIVATE LANDS

State and private lands, which in 1941 harbored 59.4 percent of all big game in the United States, ranked fourth in density of population, with an average of 0.42 animal per 100 acres. The percentage increase over 1937, namely, 25.3 percent, is the lowest for any land-classification area (table 25). There has been a pronounced decrease in numbers of bighorns on these areas, and the moose also has shown a notable decline.

GAME KILL

Most of the States now keep a fairly accurate account of the number of each species of big-game mammals killed. Some of these records extend back for several years, others have been kept only a few year A very few States have little idea of the actual number of animals kille legally or otherwise. In the tabulations that follow (tables 26–29 records of the kills for each year have been obtained by the Fish an Wildlife Service, in most cases directly from the State game or conservation commission. In a few instances it has been necessary t make an independent estimate. Most of the kill records are for th legal kill in open season. The illegal kill over the country as a whol is no small item and may equal in some localities more than half o the authorized kill. Michigan in 1937 estimated the illegal kill o deer at 50 percent of the legal kill. Mortality in regions with seve winter weather, as for example, northern Michigan, and with winte food shortage may eliminate deer in numbers up to 50 percent of th annual kill. Through management, these losses of deer and other big game animals are becoming less, but until conditions are greatly improved, a hunting kill of 12 percent of the big-game population is th maximum that should be permitted if a sufficient breeding stock is t be maintained. A larger proportion must, of course, be taken to reduc serious overpopulations. In the tabulations of kills (tables 26–29) States not mentioned had no open season.

In addition to the species more important as game, the kills of whic are here tabulated, there were also reported killed in 1941 by hunter 64 moose in Wyoming, 25 bighorns in Wyoming, 100 Rocky Mountai goats in Idaho, and 300 peccaries in Arizona. Reports of the 194 hunters' take show 121 moose killed in Wyoming, 22 bighorns i Wyoming, 100 Rocky Mountain goats in Idaho, and 77 peccaries i Arizona. A considerable number of buffaloes were killed in 1941, an more in 1942, 200 from Yellowstone National Park alone, but no complete record of the kill is available.

TABLE 26.—*Deer killed legally in the United States in 1940, 1941, and 1942*

State	Number killed			State	Number killed		
	1940	1941	1942		1940	1941	1942
Alabama	1,000	1,000	1,000	New Mexico	5,000	7,000	6,0
Arizona	2,000	3,500	6,120	New York	13,661	13,333	13,7
Arkansas	700	600	866	North Carolina	3,000	5,000	16,0
California	46,317	43,493	25,902	North Dakota	1,600	3,000	-----
Colorado	23,000	16,925	25,293	Oregon	20,000	20,000	37,0
Connecticut	400	434	800	Pennsylvania	45,000	21,250	27,7
Florida	1,539	2,300	3,400	Rhode Island	Closed	75	Clos
Georgia	1,500	3,000	4,000	South Carolina	5,000	5,000	5,0
Idaho	15,000	14,036	13,627	South Dakota	1,500	1,710	2,0
Louisiana	2,000	1,200	1,200	Tennessee	Closed	Closed	5
Maine	21,000	19,881	22,591	Texas	30,000	28,800	40,0
Maryland	424	311	395	Utah	40,000	50,000	66,0
Massachusetts	3,000	2,500	2,526	Vermont	3,304	3,067	3,2
Michigan	45,000	74,918	75,736	Virginia	1,565	1,543	1,9
Minnesota	15,000	Closed	76,806	Washington	30,000	21,700	30,0
Mississippi	400	385	700	West Virginia	1,116	1,064	1,5
Montana	10,000	17,000	18,000	Wisconsin	33,138	40,403	40,0
Nevada	1,760	1,200	1,200	Wyoming	5,564	8,043	11,9
New Hampshire	5,740	4,209	5,000				
New Jersey	2,500	2,279	2,622	Total number killed	437,728	440,159	590,4

TABLE 27.—*Elk killed legally in the United States in 1941 and 1942*

State	Number killed		State	Number killed	
	1941	1942		1941	1942
Arizona	153	325	South Dakota		125
Colorado	2,388	4,893	Utah	780	757
Idaho	3,204	3,184	Virginia	6	666
Montana	5,500	11,000	Washington	1,600	2,000
New Hampshire	56		Wyoming	5,076	9,046
New Mexico	42	175			
Oregon	3,741	2,250	Total number killed	22,546	33,761

TABLE 28.—*Prong-horned antelopes killed legally in the United States in 1941 and 1942*

State	Number killed		State	Number killed	
	1941	1942		1941	1942
Arizona	290	481	South Dakota		475
California		405	Wyoming	5,337	6,050
Idaho	800	900			
New Mexico	455	547	Total number killed	8,260	9,459
Oregon	1,378	601			

TABLE 29.—*Black bears killed legally in the United States in 1941 and 1942*

State	Number killed		State	Number killed	
	1941	1942		1941	1942
Arizona	200	200	New York	60	154
California	200	1,500	Oregon	300	400
Colorado	300	230	Pennsylvania	586	168
Georgia	100	200	Vermont	60	
Idaho	200	200	Virginia	100	133
Maine	399		Washington	1,500	1,500
Michigan	754	785	West Virginia		150
Minnesota	90	750	Wyoming	74	49
Montana	200	200			
New Mexico	97	100	Total number killed	5,220	6,719

A comparison of the annual legal kill of deer and of all other game animals with their respective populations in the United States shows that in both 1941 and 1942 the legal kill was less than 10 percent of the numbers existing at the end of the preceding calendar year. The big-game population at the beginning of a hunting season consists of the numbers surviving the hunter kill of the previous season and considerable winter destruction plus the young stock of the new year. Young of the year should not be considered huntable. The big-game population that remains at the close of the calendar year is the supply upon which should be based calculations for the hunting take of the following autumn, consideration being given, of course, to the year's increase in young as a contribution toward a surplus for the following year. Under ordinary conditions where big game exists in sufficient numbers for hunting, a 10-percent kill of the population of the previous year is safe in respect to continuation of the supply. Under improved management the kill might be increased to 12 or more percent. Very seldom, and then only with unusual surpluses, can the take be increased to 15 percent and there yet remain a sufficient reserve and breeding stock. In the calculations presented in tables 30 and 31, all animals are considered huntable, even though a large number on refuges and national parks are protected. In estimating the game weights, it was assumed that an average deer will weigh 100 pounds; elk, 300; moose, 450; antelope, 80; bighorn, 120; mountain goat, 110; bear, 150; and peccary, 40 pounds. All weights are for "hog-dressed" carcasses, that is, bled and disemboweled.

Table 30.—*Percentage kill of deer and the estimated weight, 1941 and 1942*

Year	Huntable population	Number killed	Percent of population killed	Estimated weight (hog-dressed)
				Pounds
1941	5,372,958	440,159	8.2	44,015,900
1942	6,089,172	590,496	9.7	59,049,600

Table 31.—*Percentage kill of all big game and the estimated weight, 1941 and 1942*

Year	Huntable population	Number killed	Percent of population killed	Estimated weight (hog-dressed)
				Pounds
1941	5,964,391	476,674	8.0	52,259,100
1942	6,748,414	640,755	9.5	71,013,640

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DETERMINATION OF WATER QUALITY

By
M. M. ELLIS, B. A. WESTFALL, and MARION D. ELLIS

RESEARCH REPORT 9

ABSTRACT

Methods are presented for the determination of those characteristics of natural waters which are of major importance to the aquatic biologist in connection with fisheries problems. Both unpolluted and polluted waters have been considered, and procedures for the evaluation of pollution hazards outlined. Usually more than one method for each type of determination is offered to meet the different degrees of accuracy required in the several types of studies.

The procedures presented have been in actual use in the Water Quality Laboratories of the United States Fish and Wildlife Service so that the ranges of reliability as discussed for the several methods have been established by both field and laboratory tests.

UNITED STATES DEPARTMENT OF THE INTERIOR
J. A. Krug, Secretary

FISH AND WILDLIFE SERVICE
Albert M. Day, Director

Research Report 9

DETERMINATION OF WATER QUALITY

By

M. M. ELLIS, B. A. WESTFALL, and MARION D. ELLIS

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CONTENTS

Page

- Introduction 1
- Collection and fixation of water samples 1
  - Samples for immediate use 2
  - Samples for analysis at the laboratory 4
- Dissolved oxygen 5
  - Collection and preparation of samples 6
  - Analytical procedures for dissolved oxygen 10
    - Winkler method 10
    - Amidol method 21
  - Evaluation of dissolved oxygen determinations 23
- Oxygen demand and oxygen consumed 25
- Specific conductance 29
- Hydrogen-ion concentration, pH 34
  - Glass electrode 34
  - Colorimetric determinations of hydrogen-ion concentration 37
  - Spotting tests for pH 41
  - Evaluations of pH determinations 42
- Alkalinity and acidity 45
  - Alkalinity 45
  - Acidity 47
  - Methods 47
  - Calculations of alkalinity 49
  - Reagents for alkalinity and acidity determinations 51
- Suspended matter 51
  - Coarse material 52
  - Rapidly settling particles and direct sedimentation 52
  - Slowly settling particles and turbidity measurements 55
  - Settleable solids 59
  - Light suspended matter 60
- Water hardness 60

Page

- Calcium and magnesium 63
- Nitrogen determinations 65
  - Ammonia nitrogen 65
  - Organic nitrogen 68
- Iron determinations 71
- Manganese 73
- Copper 74
- Zinc 75
- Sulfates 77
- Sulfides, sulfites, and other non-sulfate sulfur compounds 78
- Phosphate determinations 79
- Fluorides 81
- Chlorides 83
- Chlorine 84
- Acetylene 87
- Special determinations 88
  - Arsenic 89
  - Aluminum 89
  - Cyanides 89
  - Lead 89
  - Phenols, cresols, and related compounds 89
  - Selenium 90
- Exploratory tests 90
  - Chlorides 91
  - Sulfates 91
  - Phosphates 91
  - Sulfides 91
  - Chlorine 91
  - Iron 91
- Fluorescence 92
- Effluents and trade wastes 93
  - Hydrogen-ion concentration action 94
  - Specific conductance values 95
  - Oxygen demand 95
  - Bioassays 96
  - Fractionation of effluents 97
- Evaluation of pollution hazards 100
  - Bioassays 102
  - Biotic surveys 107
- Acknowledgements 109
- Literature cited 110

INTRODUCTION

This manual on water quality has been designed to present a system for the determination and evaluation of those conditions and substances of primary interest to the aquatic biologist, which occur in natural and polluted waters. Many of the procedures are applicable, however, to various problems in sanitary engineering and in trade waste disposal. The methods chosen have been used by the authors in the Water Quality Laboratories of the United States Fish and Wildlife Service and in actual field operations, in most cases, over a period of years. It has been possible in general, therefore, to select analytical sequences for which the technical limitations are rather well established. Where it seemed desirable, a choice of procedures, including both routine and research methods, is offered.

As water quality is a complex defined by the several specific characteristics of the water under examination, the designation of water quality depends upon the presence or absence of those substances which determine whether the water will serve a particular purpose. It is quite possible, therefore, to rate a given water as good for one use and poor for another. As the aquatic biologist is concerned for the most part with conditions which affect living aquatic organisms, the substances and characteristics discussed in this manual have been selected because they are essential to aquatic life, influence conditions which are essential, or are specifically harmful to aquatic organisms. However, water characteristics cannot be assembled under three simple groupings as this statement might imply, for the same substances may be harmful in one combination and innocuous in another. Nevertheless, certain conditions must be maintained in an aquatic environment if life is to survive even a short time, and certain others in addition are necessary if life is to continue successfully over a period of time. Therefore, the sequence suggested by the groupings given above has been followed in the general plan of the procedures presented here for the determination of water quality[1].

COLLECTION AND FIXATION OF WATER SAMPLES

As various substances in both natural and polluted waters either change on standing or may actually disappear from the sample in a short time, and as the handling of the sample during collection may seriously alter the quantities of dissolved gases, acids, and volatile compounds, special collecting devices are required for certain water samples to be used in particular analyses, and special fixation routines must be followed after these samples have been collected. On the other hand, samples for some purposes require very little special handling and may be dipped directly from the stream.

A complete study of water quality at any given point will require several types of samples.

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[1] Approved for publication May 26, 1945.

SAMPLES FOR IMMEDIATE USE

For Dissolved Oxygen and Other Gases

As contamination of the sample with air or other gases present in the vicinity must be avoided and as samples should be taken at various levels if the water is more than six feet deep, a sampling device which will insure both accuracy of the sample and security against contamination must be used. For such samples the Foerst sampler or the bottle-train sampler are currently used.

Foerst Sampler

The Foerst modification of the Kemmerer sampler is recommended for most field work. This sampler consists essentially of

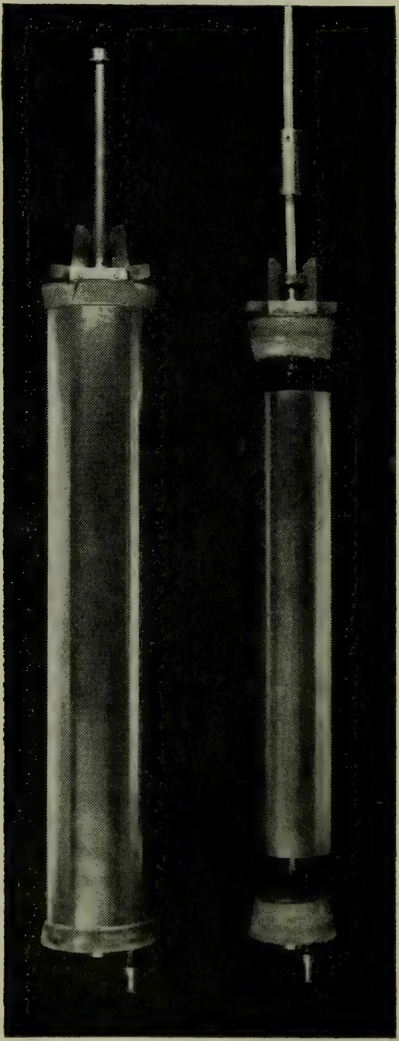

Figure 1. —˙ Foerst Sampler.

a hollow cylinder usually made of brass although for special work where it is desirable to view the entire sample, transparent plastic can be used. This cylindrical tube is open at both ends but may be closed at both ends simultaneously by a trip-mechanism. The trip is released by dropping a weight down the line to which the sampler is attached. After the sampler is closed, the individual sample bottles are filled through a rubber tube attached to a spring valve in the bottom of the sampler and to a glass tube inserted into and resting on the bottom of the sample bottle. Care must be taken to avoid all bubbles, to overflow the sample bottle by at least three volumes of water and to withdraw the glass tube from the sample bottle slowly while the water is still flowing.

Bottle Train Sampler

The bottle train is also an efficient sampler. Four or more bottles sealed with rubber stoppers are connected in a train by glass tubes so that the water enters the lowest bottle first and continues on through the three other bottles so that when all four bottles have been filled, the first bottle, which is the true sample, has been flushed out by three volumes of the water which is being sampled, before the actual sample was caught. Bottle trains are easily constructed and, when properly weighted and provided with a trip-string to open the train at any desired time, can be used even for deep sampling.

Siphon Sampling

When it is necessary to clarify large samples by flocculation (v. i.) and in many laboratory tests, bioassays, and chemical oxygen-demand determinations, samples can be drawn by a short simple siphon. Long siphons must not be used if the sample is being collected for dissolved gases because of the pressure changes which may be produced. The siphon should be dry and clean at the start and the limb to be introduced into the water made of glass tubing. Lower this glass limb slowly into the water to avoid aeration and to permit the complete removal of air from that portion of the siphon in the water. The sample may then be started from the free end of the siphon and, after flushing the siphon, led into or connected with the sample bottle.

Samples for dissolved gases must be transferred from the sampler into sample bottles which can be securely stoppered without the inclusion of air bubbles. For dissolved oxygen, special sample bottles are required (p. 7) and these special bottles are very desirable also for samples to be used in the determination of other gases.

FOR SPECIFIC CONDUCTANCE, pH, AND SPECIFIC GRAVITY

Use either the Foerst or the bottle-train sampler and transfer samples to magnesium-citrate bottles. Close bottle at once and use sample as soon as possible.

FOR TURBIDITY AND SUSPENDED MATTER

Samples for turbidity and suspended matter should be collected directly, if possible, in the sedimentation tubes or Imhoff cone (see section on Suspended Matter). If this is not feasible, or if the samples are to be taken from levels below the surface, use the Foerst sampler and transfer to suitable tubes or bottles.

SAMPLES FOR ANALYSES AT THE LABORATORY

Generally the Foerst sampler is convenient for most types of samples so its use is recommended. If samples are to be returned to the laboratory, fixation is usually required.

FIXED SAMPLES

Pint, quart, or half-gallon glass fruit jars, with all glass (no metal) lids of the self-sealing type are excellent for water samples. These jars can usually be obtained even in small towns and villages and are packed in corrugated cardboard boxes convenient for handling.

The jar should be thoroughly washed and rinsed several times in the water with which it is to be filled. It is advisable to fill the jar to within a half-inch of the top, then add the fixing agent. Measured quantities of water and of the fixing agent must be taken if non-volatile fixing agents are used so that the dilution resulting from the fixing compound can be computed. Volatile fixing agents do not require measured samples. If plankton is present, the sample should be filtered through coarse filter paper or absorbent cotton before the fixing agent is added.

Acid Fixation

If determinations of ammonia are to be made, a measured quantity of c. p. concentrated sulfuric acid should be added to the measured sample. One milliliter of acid per liter of sample is usually ample, unless the water be strongly alkaline, in which case acid must be added until the sample gives an acidic reaction near pH 4.0 with an external indicator or test paper. Samples fixed with acid should not be used for determination of iron, manganese, and other metals, if there be any silt present in the sample as the acid can dissolve metallic elements from silt and spurious values for the metals will result.

Toluene or Chloroform

As many water samples contain bacteria and other organic matter, it often is desirable to fix the sample so that bacterial action will be stopped. This type of fixation is required for all samples to be held more than a few hours if any appreciable quantity of organic matter is present. A few drops to 1 ml. of either toluene or chloroform if added to the sample in the jar just before it is sealed, will prevent bacterial decomposition of organic material. The fixing agent subseqently can be removed from the sample by evaporation, aeration, or heat in the laboratory so that neither the toluene nor the chloroform need be calculated as a diluent.

UNFIXED SAMPLES

Most effluents should be collected directly in glass jars or large glass-stoppered bottles. If possible, several samples should be obtained and some of them fixed with toluene or chloroform. However, it is not desirable to fix many chemical and industrial effluents unless the bacterial or organic content is high. These samples should be sealed as soon as possible with the minimal amount of air to prevent oxidative changes. It must be remembered that many effluents change quite rapidly after collection and due consideration must be given to these changes in subsequent bioassays.

DISSOLVED OXYGEN

The accurate determination of dissolved oxygen is highly important in water-quality studies not only because oxygen is indispensable to fishes and other aquatic organisms, but also because knowledge of the exact amount of dissolved oxygen is essential in solving many problems which confront the aquatic biologist, the sanitary engineer, and the industrial chemist. The measurement of the effect of specific oxyphilic pollutants, the charting of stream pollution, the computation of a maximal load of organic pollution which any given mass of water can tolerate and still remain habitable for aquatic life, and the biochemical exploration of deep lakes and impoundments are among the many field investigations requiring precise analyses for dissolved oxygen.

Although the degree of accuracy requisite in the various types of field and laboratory studies varies, any determination of dissolved oxygen requires the careful observance of several precautions if a dependable value is to be obtained. The amount of oxygen gas in solution in the water can be altered easily by either improper preparation or handling of the sample; and the analytical methods for dissolved oxygen have certain chemical limitations which cannot be disregarded. In addition, oxygen determinations must be made as soon as possible after the sample is taken, which in field studies necessitates portable apparatus for streamside use. However, accurate determinations of dissolved oxygen can be made if reasonably simple procedures of sampling and analysis are followed. A system for disolved oxygen studies that will meet the conditions encountered in both good and polluted water is presented. It is recognized that many other procedures could be followed, but the methods offered here have proved dependable and practical in a variety of situations.

In this system there are choices of sampling equipment depending upon the degree of accuracy required and the conditions under which the samples are to be taken. The selection of an analytical sequence is not optional, however, as these procedures have been developed for specific water types. Consequently orientation tests (q. v.) should be made before any quantitative, dissolved-oxygen analyses are attempted.

COLLECTION AND PREPARATION OF SAMPLES

Careless manipulation of the sampling devices or improper handling of the sample once it is obtained can change dissolved-oxygen content of water so that analysis is useless. It must be borne in mind while sampling for dissolved oxygen that slight changes in pressure or temperature to which the sample may be subjected, agitation of the water in the presence of air, and entrainment of bubbles of air or other gases with the sample, readily alter the amount of dissolved oxygen in any given sample. Therefore, it is of great importance that the sample be taken without undue agitation, bubbling, or reduction of pressure, and that it be held as nearly as possible at the temperature of the water at the time of sampling until the reagents for oxygen fixation have been added. Ideally, the sample should be fixed immediately after collecting and for this purpose the writers use a small box containing the required chemicals which can be carried to the actual site of the sampling operations.

It is not always possible in the field to meet these specifications absolutely but both the samplers and the sample bottles have been designed to reduce errors from pressure, bubbling, and agitation, to the minimum, and should it be necessary to hold unfixed samples for a short time, they can usually be kept near the proper temperature by placing them in a bucket of water taken from the same source as the sample or by covering the outside of the bottles with wet cloths if the air temperature is high.

SAMPLERS

Either the Foerst or the bottle-train sampler (p. 2) will provide accurate and uncontaminated samples for dissolved oxygen under most field conditions. In laboratory tests, recourse must be had to either the siphon or some other device which will meet the specific difficulties of sampling under experimental conditions.

CLARIFICATION

If the water to be sampled carries a large amount of mud or other suspended matter which does not settle out readily or rise to the top on standing, so that a suitable sample can be obtained from a large sample by siphoning, it is usually desirable to remove the suspended matter by flocculation before dissolved oxygen analyses are attempted. A large sample, 1 - 3 liters, is procured in a glass-stoppered sample bottle, with the usual precautions. The glass stopper is carefully removed and 10 ml. of 10-percent alum solution (potassium aluminum sulfate) added per liter of sample from a glass pipette, the tip of which has been lowered at least a centimeter below the surface of the sample. The alum solution is followed immediately by 1 or 2 ml.

of approximately 35-percent sodium hydroxide solution. The bottle is then carefully stoppered without entrainment of air and gently rotated until the solutions are thoroughly mixed. A heavy precipitate of white aluminum hydroxide will be formed and will appear in curds throughout the bottle. Place the bottle in an upright position and allow the precipitate to settle. As the aluminum hydroxide moves to the bottom of the bottle, the sample will be clarified by flocculation, (Ruchhoft and Moore, 1940).

When the top two-thirds of the sample bottle has cleared, a clear sample can be drawn through a siphon into a smaller sample bottle. If very accurate results are required, the dilution of the original sample by the addition of reagents for flocculation must be computed. For general work, this correction may be disregarded. It is very important that the quantities of alum solution and sodium hydroxide be added exactly as directed for an excess of alkali could raise the alkalinity of the sample to pH 11 or above, at which levels of alkalinity many organic substances will take up dissolved oxygen. If too much alkali is used, therefore, in the flocculation process, the final dissolved oxygen reading will be too low owing to the loss of dissolved oxygen when organic substances are present. Ruchhoft (1941) states that this procedure for clarification by flocculation is very effective for raw sewage and river-mud suspensions and that using the supernatant fluid from this clarification, the dissolved oxygen may be determined by the rapid Winkler method (p. 13). The writers have confirmed these observations.

A second procedure, using a copper-sulfamic acid mixture (Ruchhoft, 1941), for clarification of samples containing activated sludge not only clarifies the sample, but inhibits oxygen utilization. A large sample (one liter or more) is collected with the usual precautions in a glass-stoppered bottle and 10 ml. of the copper-sulfamic acid solution added per liter of sample. The bottle is restoppered and rotated until the solution is thoroughly mixed with the sample. The bottle is then placed in an upright position, when a coagulated floc soon settles out leaving a clear supernatant fluid which may be siphoned off for dissolved-oxygen determinations.

This copper-sulfamic acid mixture is prepared by dissolving 50 grams of copper sulfate, 32 grams of sulfamic acid, and 25 milliliters of glacial acetic acid in distilled water to make one liter.

SAMPLE BOTTLES

Three types of sample bottles have been used in the work of the Water Quality Laboratories of the United States Fish and Wildlife Service for the past 10 years, choice depending upon the degree of accuracy in the analysis for dissolved oxygen required, and the conditions under which the sample is to be taken.

Precision-Sample Bottles

Three forms of precision-sample bottles have been found desirable to meet different conditions in sampling. The first (fig.

2, left) consists of a glass cylinder of 100 to 300 ml. capacity, tapering to a small tube at each end, which tubes carry a two-way, glass stopcock opening into either the glass cylinder or a short waste tube. When the precision bottle is to be filled, it is mounted vertically in a clamp. A small piece of glass tubing carrying short, rubber connectors is attached to the Foerst sampler or other source of water to be sampled. Both top and bottom stopcocks are set to allow the water to flow in at the bottom and out of the top of the sampler. The water from the supply to be sampled is then allowed to flow through the sample bottle until at least three volumes have passed through it. When a satisfactory sample has been obtained, both stopcocks are closed. Measured quantities of reagents for the dissolved oxygen analysis (v.i.) are subsequently introduced by means of micro-pipettes through a small glass sleeve which fits tightly onto the terminal tube leading from the glass stopcock. When the glass sleeve is filled with the proper amount of reagent, the top stopcock is opened so that fluid can enter the sample bottle. The bottom stopcock is opened then to allow fluid to escape from the sample bottle thereby drawing the reagent into the sample. The glass sleeve must be removed and cleaned after each use of a reagent and the stopcock flushed out via the side tube.

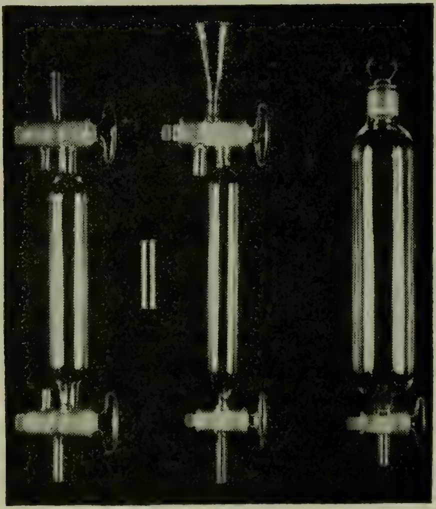

FIGURE 2. — Precision-sample bottles: left, 2-way stopcock at top and bottom for use with glass sleeve for introduction of reagents; center, funnel-top type; right, large size for dilution of samples.

A second form of precision-sample bottle (fig. 2, middle) has only a one-way stopcock at the bottom and a two-way stopcock surmounted by a funnel for reagents at the top. The funnel is washed out after each use of reagent through the side tube of the stopcock.

A third form (fig. 2, right) has only a single, one-way stopcock at the bottom and a glass-stopper at the top. This is the largest of the three forms and is used when it is desirable to dilute a sample of polluted water with water of known dissolved-oxygen content. The reagents are added directly at the top by means of micro-pipettes.

These forms of precision bottles can be accurately calibrated with mercury so that both the total capacity of the bottle and the capacity of the bores of the stopcocks are known. Full corrections for the percentage of loss of a sample during the addition of reagents can be made accordingly.

Using a precision bottle and following the fixation with an electrometric titration, a very high degree of accuracy for dissolved-oxygen determinations can be obtained. This apparatus and the electrometric titration are recommended only for work where very high accuracy is required, as in metabolism determinations and bioassays in which the oxygen consumption must be computed. In the hands of an experienced operator, this precision bottle and electrometic titration procedure together with the proper sequence for oxygen determination will give results accurate to within 0.002 to 0.003 p.p.m. of dissolved oxygen.

Glass-Stoppered Sample Bottle

Bottles, with stoppers ground to fit, preferably of pyrex glass, of 200 to 300 ml. capacity make excellent sample bottles for dissolved oxygen if the end of the ground portion of the glass stopper is held against a revolving emery wheel and rotated until the edge is definitely beveled so that air bubbles will not be caught under the stopper when it is inserted into a completely filled bottle. The standard glass-stoppered, biochemical oxygen-demand (B.O.D.) bottles used by sanitary engineers, although more costly, are excellent for this purpose as these bottles are provided with a tapered-end glass stopper.

Occasionally it is necessary to collect a large sample, 1-3 liters, for special treatment (p. 6.) before the determination of dissolved oxygen is made. For this purpose large, glass-stoppered acid bottles are quite satisfactory if the ends of the stoppers are tapered or pointed.

The glass-stoppered sample bottle of whatever kind must have a round shoulder so that no bubbles will be caught in the bottle when it is being filled, must be provided with a ground glass stopper which fits accurately and securely into the neck of the bottle, and which is tapered sufficiently at the end to prevent the trapping of air bubbles below the stopper when it is lowered into the neck of the completely filled bottle.

Glass-stoppered sample bottles should be used in both field and laboratory when an accuracy of at least 0.01 p.p.m. of dissolved oxygen is expected.

In filling these glass-stoppered sample bottles care must be taken to flush the bottle with at least three volumes of the water being sampled and to withdraw the glass tube, through which the sample is entering the sample bottle, slowly from the bottle while the water is still flowing.

Unless there are specific reasons to the contrary, this type of bottle is preferred for routine dissolved oxygen determinations.

Magnesium Citrate Bottle

The bottle commercially known as a magnesium-citrate bottle (fig. 3, right) is satisfactory for dissolved oxygen samples in field work where a large number of samples must be taken quickly and where accuracy greater than 0.2 p.p.m. of dissolved oxygen is not essential.

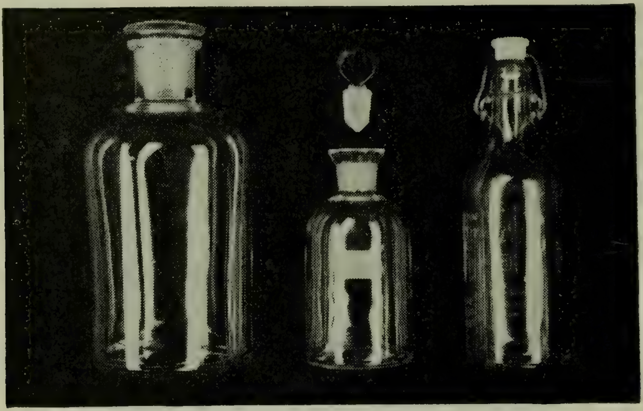

Figure 3. — Sample bottles: left, large size for flocculation; center, regular glass-stoppered sample bottle for dissolved oxygen (note tapered-end stopper); right, self-sealing, magnesium-citrate bottle.

The magnesium-citrate bottle carries a smooth porcelain or glass stopper which can be snapped in place by means of a wire loop on the side of the neck of the bottle. These bottles are filled with the same precautions as the other two types of sample bottles, and the bottles sealed by snapping down the stopper which carries a rubber gasket. The gasket must be changed frequently and should be properly cleansed after using. The authors have cut gaskets for these magnesium-citrate bottles from automobile innertubes and have found these homemade gaskets to be superior in resistance to analytical reagents to the stock gaskets which come with the bottles. If no greater accuracy than 0.2 p.p.m. dissolved oxygen is desired, the loss of iodine from the treated sample into the rubber gasket is negligible during short exposures.

ANALYTICAL PROCEDURES FOR DISSOLVED OXYGEN

WINKLER METHOD

The method originally described by Winkler (1888), based on the formation of manganous compounds that are oxidized to manganic by the dissolved oxygen in the water sample, and which subsequently release iodine quantitatively from potassium iodide when the sample is acidified, still remains in principle the most useful method for both field and laboratory determinations of dissolved oxygen in water. Numerous modifications have been proposed to meet specific needs and to offset the action of substances in the water affecting the Winkler reagents. These interfering substances are discussed under orientation tests.

BASIC WINKLER METHOD

This method assures accuracy only with waters of high purity, free from interfering substances and organic pollutants and containing less than 0.05 p.p.m. of nitrate and 1.0 p.p.m. of ferrous iron.

Procedure

1. A 250-300 ml. sample is desirable, and the sample bottle should be placed in a lead-lined box approximately 3 × 4 × 12 inches so that the corrosive chemicals and overflow will not foul other equipment.
2. Open sample bottle with great care, avoiding aeration of the surface of the sample with bubbles or by undue agitation, and add exactly one ml. of manganous sulfate (or chloride) solution from a glass pipette. The point of the pipette must be lowered an inch or more into the sample bottle and the heavy manganous sulfate solution introduced rather slowly so that it will sink to the bottom.
3. Add at once one ml. of alkaline-potassium-iodide reagent in a similar manner from another glass pipette. (Caution — use a separate pipette for each solution!).
4. Close bottle immediately and mix thoroughly by repeated, rapid inversions of the bottle in the hand for from 40 to 60 seconds. During this mixing, a milk-white precipitate of manganous hydroxide will form and as this compound combines with the dissolved oxygen in the water, yellowish-brown manganic compounds will appear. If the milk-white color persists, very little dissolved oxygen is present. After shaking the sample bottle for approximately one minute, return the bottle to the lead-lined box and allow the precipitate to settle at least halfway down the bottle, i.e., there should be no precipitate in the top half of the bottle when the next step is started.
5. Open sample bottle carefully as before and add two ml. of concentrated sulfuric acid (or hydrochloric acid) by bringing the point of the pipette against the neck of the sample bottle a few millimeters below the surface of the sample so that the acid will flow down the inside wall of the bottle. Close bottle immediately after the acid is added and mix thoroughly by inverting the bottle several times. During this mixing, the precipitate, either white or brown, should dissolve completely and the sample will become clear, developing a yellowish brown color due to the iodine liberated. The depth of this color is proportional to the amount of dissolved oxygen present so that the analyst may estimate approximately the amount of dissolved oxygen present in the sample in advance of titration. Sometimes part of the precipitate will not dissolve owing to the formation of compounds other than the manganic compounds

involved in the liberation of iodine, by the reaction of the reagents with the impurities in the water. If such an insoluble precipitate forms, it may be disregarded but care must be taken not to include any of the undissolved precipitate in the aliquot portion of the sample taken subsequently for titration.

6. When the precipitate has dissolved and the sample has become uniformly colored, fill a 100 ml. graduated flask with the clear part of the sample (200 ml. may be used if greater accuracy in titration be desired). To the 100 ml. or 200 ml. aliquot taken from the first sample add, from a pipette, the exact amount of treated sample required to correct for the volume of sample lost by displacement when the manganous sulfate and the alkaline, potassium-iodide solutions were added during the process of fixation. The volume of this correction can be computed by substituting actual values in the following equation:

$$\frac{\text{ml. of treated sample taken} \times \text{ml. capacity of sample bottle}}{\text{ml. capacity of sample bottle} - \text{ml. of manganous sulfate and alkaline potassium iodide}} = \text{Total volume of treated sample required}$$

Pour the corrected aliquot sample into a 250-ml. beaker and wash out the flask with a few ml. of distilled water, adding the washings thus obtained to the sample in the beaker.

7. Titrate over a white surface with standardized, sodium-thiosulfate solution until only a pale straw-yellow color remains. Add 0.5 ml. (about 10 drops) of starch solution and continue titration until the blue color completely disappears for the first time. This must be taken as the end-point as various impurities in water may cause a return of the blue color a few seconds to a few minutes after it is first discharged and if the titration is continued, an erroneously high reading for the dissolved oxygen will be obtained.

COMPUTATION OF RESULTS

The sodium thiosulfate is standardized (p. 19) so that a substitution of real values in the following equation will give the dissolved oxygen in parts per million (D.O. p.p.m.).

$$\frac{1000}{A} \times B \times F = X$$

A equals ml. of aliquot (uncorrected i. e. 100 or 200 ml.) of treated sample.
B equals ml. of sodium thiosulphate used in titration.
F equals factor value of one ml. of thiosulfate solution in milligrams dissolved oxygen.
X equals p. p. m. of dissolved oxygen in sample.

LIMITATIONS

Approximately one minute of mixing time must be allowed after the addition of the manganous sulfate and the alkaline, potassium-iodide solution so that the consumption of the dissolved oxygen present in the water by the manganous hydroxide formed from the reagents can be completed. For uniformity, therefore, the mixing should be timed rather accurately to be not less than 40 seconds nor more than 60 seconds. After the acid is added, the titration should be made as soon as possible for the sample is not dependable without special treatment for more than one hour in this phase if even very small quantities of ferric iron or various organic substances are present. Although several procedures for "fixing" the sample after the iodine has been liberated have been proposed, they should be avoided if possible as this procedure not only adds an additional step to the routine but may introduce errors of various sorts.

RAPID, UNMODIFIED WINKLER METHOD

This method must be used if the sample contains considerable organic pollution but is otherwise free from disturbing material. However, it does not correct for nitrites, iron, sulfites, and similar interfering substances. This procedure will give valid, dissolved-oxygen determinations in the presence of organic matter up to the approximate equivalent of 5,000 p.p.m. of dextrose.

PROCEDURE

Follow the same routine as given for the basic Winkler method except:

1. Use 2 ml. of both manganous-sulfate and alkaline-iodide reagents.
2. Upend the bottle and agitate for not more than 20 seconds.
3. Add 2 ml. of acid as soon as the precipitate has settled a half inch from the top of the bottle, or not later than 15 seconds after the mixing is completed.
4. Titrate as soon as possible after the acid has dissolved the brown precipitate.

SAMPLE-BLANK MODIFICATION OF THE WINKLER METHOD

This procedure, based on the sample-blank routine which is made use of in so many biochemical analyses, has been evolved by various students of dissolved oxygen (Skopintsev and Mityagina, 1939), and the particular sequence presented here is quite similar to that recently published by Adams, Barnett, and Keller (1943). The objective, regardless of the specific routine, is to compensate for errors due to various interfering substances by analyzing simultaneously two bottles of the sample and varying the sequence of reagents so that all of the deductible errors will appear in one bottle. The chemical background of these sequences and their coverage of the interfering substances is given in detail by Adams, Barnett, and Keller (1943).

This method must be used if nitrites, ferric or ferrous iron, sulfites, and similar interfering substances are present, i.e., if either of the first two orientation tests are positive, q.v. This procedure will give excellent results for both unpolluted and polluted waters unless large amounts of organic, oxygen-consuming substances are present. This sequence should be used routinely for all waters unless excessive organic pollution is present, as it corrects for both types of interfering substances. Although the sample-blank method requires more time per sample, the dependability of the results amply compensates for the extra time.

PROCEDURE

1. Fill 2 matched, 250-300 ml., glass-stoppered sample-bottles (use precision bottles if greater accuracy is required) with aliquot parts of the same sample. Stopper immediately. Mark these so that one may be recognized as the true sample "A" and the blank "B."
2. To the true sample A, add exactly 2 ml. of iodized, alkaline-iodide solution (not the alkaline-iodide solution used in the basic Winkler method), followed by 2 ml. of manganous-sulfate reagent. Restopper, upend to mix reagents, and agitate by alternately reversing the bottle in the hand for exactly 40 seconds. Put bottle A aside to allow precipitate to settle.
3. While precipitate is settling in bottle A, add to bottle B, the blank, in the order indicated, 2 ml. of iodized, alkaline-iodide solution, 2 ml. of sulfuric acid, and 2 ml. of manganous-sulfate reagent. After the addition of each reagent, restopper the bottle and upend it to allow for complete mixing, waiting 10 to 15 seconds before adding the next reagent. When these additions have been made, put bottle B aside and return to bottle A.
4. After the precipitate has settled, add 2 ml. of sulfuric acid to bottle A, restopper, and mix. As soon as the precipitate has dissolved, this sample should be titrated.
5. Take exactly 100 or 200 ml. of the clear fluid from bottle A and add to it sufficient additional fluid from A to make correction for fluid lost by reagents (p. 12). Titrate over a white surface with standardized sodium thiosulfate to starch end-point (p. 12).
6. Prepare a similar portion of the fluid from bottle B and titrate to starch end-point with standardized sodium thiosulfate.

CALCULATION OF DETERMINATION

Subtract the milliliters of sodium thiosulfate required to titrate the aliquot from bottle B from the thiosulfate used to titrate the aliquot from A. Using this value complete calculation as given on p. 12.

RAPID SAMPLE-BLANK MODIFICATION

This procedure must be used if interfering substances are present as shown by either of the first two orientation tests and if organic oxygen-consuming substances are present in sufficient quantities to require a rapid method.

PROCEDURE

Use the sequences given for the sample-blank method with these modifications.

1. Mix the true sample for 20 seconds or less after adding the iodized, alkaline-iodide and manganous-sulfate solutions.
2. Add acid to this sample as soon as possible after the mixing is completed, i.e., in 15 seconds or less.
3. Titrate this sample as soon as the precipitate is dissolved.

ORIENTATION TESTS

Four sequences are offered above for Winkler determinations depending upon the presence or absence of various interfering substances. However, as the aquatic biologist is confronted with the necessity of determining dissolved oxygen in both polluted and unpolluted waters and as often the pollution of the water is not detectable by visual or olfactory inspection, orientation tests should be made before the samples for exact quantitative analyses are prepared to determine which of the sequences should be followed. Otherwise subsequent analyses may show the presence of interfering substances which may have invalidated the previous determinations, and as the dissolved-oxygen determinations must be made at the streamside, it is often not possible to repeat them.

In field water-quality studies as well as in various experimental and industrial procedures, nitrites, ferrous and ferric iron compounds, sulfites, sulfides, polythionates, and various other sulfur compounds are the substances most frequently encountered which interfere with the correct determination of dissolved oxygen when using the Winkler reagents. Both nitrites and ferric iron compounds liberate additional iodine from the potassium iodide during the course of the Winkler procedure, so that the final titration is too high, indicating, therefore, more dissolved oxygen than the sample actually contains. On the other hand, ferrous iron, sulfites, and various organic substances remove from the treated sample, either by chemical action or by adsorption, some of the iodine liberated from the potassium iodide by the manganic compounds so that the final titration is too low and indicates less dissolved oxygen than is actually present in the sample.

In addition to these interfering substances which affect the reagents or the reaction directly, numerous organic compounds that occur in sewage or other forms of organic pollution can take up dissolved oxygen from the water or reduce some of the intermediate products of the Winkler reaction when the alkalinity is greater than pH 11. As this degree of alkalinity is attained during one phase of the Winkler procedure, some types of organic material, if present in sufficient quantities, will remove an appreciable amount of dissolved oxygen from the sample during this part of the analysis so that the final determination will be too low.

Impurities in the reagents can also limit the accuracy of the Winkler method; consequently, only tested reagents should be used.

Three orientation tests are described and the first two should be made routinely as they require very little time and will enable the analyst to proceed with confidence in his subsequent oxygen determinations. The third orientation test is rather laborious and is required only if heavy organic pollution is suspected or is obvious.

TEST FOR NITRITES, FERRIC IRON, AND OTHER SUBSTANCES CAUSING THE DISSOLVED-OXYGEN READING TO BE TOO HIGH

1. Obtain a sample of the water from the stream or source under investigation in a clean 250 ml. beaker. No precautions against aeration are necessary, i.e., the sample may be dipped up directly in the beaker. If the water is clear and free from suspended matter, it can be used without further preparation. However, as even clear water often contains plankton organisms, it is almost always desirable to filter it.
2. Filter some of the sample through clean filter paper or absorbent cotton using a glass funnel. It is necessary to remove only the larger particles of suspended matter so rapid filtration can be used.
3. Into a 50 ml. Erlenmeyer flask, measure 10 ml. of the filtered sample and add first one ml. of seven percent KI solution, and then one ml. of concentrated HCl. Rotate flask to insure mixing. If a yellow to brown color develops, substances which would cause the determination with Winkler reagents to be too high are present.

TEST FOR SULFITES, FERROUS IRON, AND OTHER SUBSTANCES CAUSING THE DISSOLVED-OXYGEN READING TO BE TOO LOW

1. Measure 10 ml. of the filtered sample into a 50 ml. Erlenmeyerflask, and 10 ml. of distilled water into a second 50 ml. Erlenmeyer flask.
2. To each flask, add exactly 1 ml. of dilute iodine solution.
3. Titrate the fluid in each flask with standard N/80 sodium thiosulfate solution, to the first, starch end-point (p. 12). If the titration of the sample is less than that of the distilled water blank, reducing substances are present which would cause the dissolved oxygen determination to be too low.

TEST FOR HEAVY ORGANIC POLLUTION

This test is designed to ascertain whether organic substances capable of taking up oxygen during the alkaline phase of the Winkler reaction are present in sufficient quantities to invalidate the dissolved-oxygen determination. As the amount of such substances required to produce disturbances in the dissolved-oxygen determination is relatively large, i. e., the approximate equivalent of 1,000 p. p. m. or more of dextrose, this test is necessary only when heavy organic pollution is obvious or suspected.

1. Samples for this test must be collected in a sampler and handled in sample bottles with the usual precautions against contamination with air.
2. If the water is turbid with organic matter or it is otherwise evident that a considerable amount of organic material is present subject a large sample to flocculation as described in the section on clarification.

3. Fill two 250 ml. glass-stoppered sample-bottles with aliquot parts of the same large clarified sample of the water to be tested, observing precautions for dissolved-oxygen sampling, and taking care that the two samples are as nearly identical as possible. Mark one A and one B.

4. To sample A, add 2 ml. of manganous sulfate reagent and follow with 2 ml. of alkaline-iodide solution. Re-stopper, upend the bottle for complete mixing, agitate for exactly 20 seconds, and put aside for 5 minutes.

5. To sample B, add 2 ml. of manganous-sulfate reagent only, restopper, upend for mixing, and put aside for 5 minutes.

6. At end of 5 minutes, add 2 ml. of sulfuric acid to sample A, restopper, upend for mixing and put aside until the precipitate has dissolved.

7. At end of 5 minutes add 2 ml. of alkaline iodide solution to sample B, restopper at once, upend for mixing, and agitate for 20 seconds. As soon as the precipitate begins to settle, but in no case more than 15 seconds after mixing is completed, add 2 ml. of sulfuric acid, restopper and upend at once for complete mixing of the acid. When the precipitate has dissolved, the samples can be compared.

8. Titrate individually 100 ml. samples of the clear fluid from both A and B, after precipitates have dissolved, to the starch end-point with standardized sodium thiosulfate.

9. If sample B required more thiosulfate for titration than sample A, substances capable of taking up dissolved oxygen directly from the water or indirectly from the intermediate products of the Winkler reaction, in the alkaline phase, are present.

a. If the extra thiosulfate used in the titration of B was the equivalent of less than 0.20 p. p. m. of dissolved oxygen, the oxygen-consuming substances can be disregarded unless very accurate determinations are required in which case one of the rapid methods must be used (see standardization of the sodium thiosulfate solution for calculation of dissolved oxygen equivalent p. 19).

b. If the extra thiosulfate used in the titration of B was the equivalent of 0.20 - 0.75 p. p. m. of dissolved oxygen, one of the rapid methods must be used as oxygen-consuming substances equivalent in disturbing action to 1,000 to 5,000 p. p. m. of glucose are present. The use of the rapid Winkler method is regarded as satisfactory for the determination of dissolved oxygen in the presence of these amounts of interfering organic substances (A.P.H.A. 1938).

c. If the extra thiosulfate used in the titration of B was equivalent to 0.75 p. p. m. or more of dissolved oxygen, oxygen-consuming substances are present in too large amounts to permit the use of the rapid Winkler methods, without dilution. Fill 3 precision-sample bottles with distilled water that has been shaken until well aerated and then put aside until all bubbles have cleared. Into two of these sample bottles add at the bottom (open top stopcock for overflow during filling) exactly the same quantity of the clarified sample, usually about one-half the volume of the sample bottle, with the usual precautions against contamination of sample with air. Determine the dissolved oxygen in both the distilled water and in the distilled water mixtures by the rapid sample-blank method (p. 14). The dilution with distilled water will reduce the quantity of oxygen-consuming substances so that the mixture can be determined by the rapid method. The dissolved oxygen in the original sample can be computed from the values obtained.

SULFAMIC ACID MODIFICATION OF WINKLER METHOD

As nitrites are a very common cause of interference in the determination of dissolved oxygen by the Winkler method in polluted river waters, several modifications of the Winkler procedure have been suggested to overcome this difficulty. Although nitrite interference is corrected in the sample-blank modification (p. 13), nitrites also can be eliminated and the basic Winkler method (p. 11) used (if there is no iron interference) by the addition of sulfamic acid. This method is very convenient for many river and stream waters and has been used successfully by the authors for laboratory analyses of waters in which laboratory animals had been held. Allee and Oesting (1934) found in respiratory studies of goldfishes, isopods, and daphnia that these animals gave off sufficient nitrites during experimental tests to cause marked errors in dissolved-oxygen determinations by the unmodified Winkler method. These authors believe that nitrite nitrogen should be less than 0.005 mg. per liter if the Winkler method is to be used, although Ruchhoft (1941) places the limit of nitrite interference at 0.05 p. p. m. (0.05 milligrams per liter). It is, therefore, very desirable to eliminate the nitrite factor particularly in bioassay tests and the sulfamic acid modification provides a more rapid method than the sample-blank method if there be no other interference.

Add 1 ml. of sulfamic acid reagent to a 250 to 300 ml. sample, stopper, and upend for mixing. After 20 to 40 seconds, proceed with the basic Winkler routine (p. 11). Cohen and Ruchhoft (1941) state that this procedure will remove up to 19.3 p. p. m. of nitrite.

Reagents for Winkler Procedures

As noted previously, all reagents used in dissolved oxygen determinations should be of c.p. or reagent quality and uncontaminated.

Potassium iodide, 7 per cent solution. — Dissolve 7 grams of reagent-quality potassium iodide in 50 ml. of distilled water, and add distilled water sufficient to make 100 ml. Keep in a brown, glass-stoppered bottle. Test one ml. of this solution in 10 ml. of distilled water by adding 0.1 ml. of concentrated sulfuric, or hydrochloric, acid. If the solution shows any yellow color, it should be rejected as the potassium iodide contains impurities which will interfere with its use in Winkler procedures.

Hydrochloric acid. — Concentrated, 1.19 specific gravity, c.p.

Sulfuric acid. — Concentrated, 1.84 specific gravity, c.p.

Iodine (stock) solution. — Dissolve 4 grams of pure iodine and

6 grams of potassium iodide in 50 ml. of distilled water and make up with distilled water to 100 ml. Store in a brown, glass-stoppered bottle.

Dilute iodine solution. — Add one drop of the stock solution to 100 ml. of distilled water. As this solution is used in sample-blank procedures, no greater accuracy is required in the preparation of the dilution. Store in a brown, glass-stoppered bottle. Do not use after three days.

Sodium thiosulfate (stock solution). — Dissolve 24.82 grams of crystalline, sodium thiosulfate, $Na_2S_2O_3.5H_2O$, in 700 ml. of distilled water. Add 4.0 grams of borax, $Na_2B_4O_7.10\ H_2O$. When borax has dissolved, make up to 1 liter with distilled water. This gives essentially a N/10 solution of the thiosulfate. The borax is added as a stabilizer to prevent the breakdown of the thiosulfate. This solution when stored in a brown glass-stoppered bottle will keep several weeks.

SODIUM THIOSULFATE N/80 AND ITS STANDARDIZATION

Mix 125 ml. of the stock N/10 sodium thiosulfate solution with 250 ml. of distilled water, and add 3 grams of borax, $Na_2B_4O_7.10H_2O$. When the borax has dissolved, make up to 1 liter with distilled water. This should give approximately a N/80 solution of sodium thiosulfate. However, this solution must be accurately standardized before it is used in dissolved-oxygen determinations, as follows:

Place exactly 25 ml. of N/100 potassium dichromate solution in a 250 ml. Erlenmeyer flask and add 1 ml. of the alkaline, potassium-iodide reagent and after mixing 2 ml. of concentrated hydrochloric acid. Titrate over a white surface with the N/80 sodium thiosulfate solution, which is to be standardized, until only a faint yellow color remains. Add 0.5 ml. or 10 drops of starch solution and continue titration until the first complete disappearance of all blue color. Divide 25 by the number of ml. of sodium thiosulfate required to make the titration, and multiply the quotient by 0.08. The result will be the oxygen equivalent in milligrams of 1 ml. of the thiosulfate solution. This form of standardization will suffice for ordinary field work. Where greater accuracy is required, especially where the volume of oxygen consumed by wastes or by animals is to be computed, the thiosulfate should be standardized by electrometric titration.

After the solution has been standardized, it should be stored in a brown, glass-stoppered bottle and care taken to prevent contamination as in the final analysis, the accuracy of the dissolved oxygen determination, regardless of the procedure used will be no greater than the accuracy of the standardization of the thiosulfate solution. It is recommended wherever feasible that the thiosulfate solution be standardized by electrometric titration.

The standardized solution, when properly handled, will not deteriorate for several weeks if borax has been added. Several methods for the preservation of standardized thiosulfate solutions have been proposed. Adams, Barnett, and Keller (1943) advocate the use of 10 grams of potassium furoate per liter of 0.05 N thiosulfate solution and Ulmer, Reynar, and Decker (1943) use 3.8 grams of borax per liter of 0.002 N thiosulfate. The authors prefer borax as given above because it is so readily obtainable. Frequent check standardizations of the thiosulfate solution are desirable even though it is preserved.

SODIUM THIOSULFATE N/200 SOLUTION

For determinations in which very small quantities of dissolved oxygen are involved and in precision analyses, a N/200 thiosulfate solution is desirable to give greater latitude in the titration. The N/200 solution is prepared by adding 50 ml. of the stock N/10 thiosulfate solution to 500 ml. of distilled water in which 3.8 grams of borax have been disolved, making up to 1 liter with distilled water. This solution should be standardized with N/100 potassium-dichromate solution by electrometric titration, and stored in a brown, glass-stoppered bottle where it will keep for several weeks if not contaminated.

POTASSIUM-DICHROMATE SOLUTION

This solution should be made up with great care in the laboratory as the accuracy of the standardization depends upon this solution. It can be carried for months in the field without deterioration.

Select crystalline pieces of reagent quality potassium dichromate, $K_2Cr_2O_7$, and dry for an hour in an oven at about 125° centigrade. Cool and weigh exactly 0.4904 grams and dissolve in distilled water to make 1 liter. Store in a glass-stoppered pyrex bottle. Protect from strong light, evaporation, and contamination of any sort. One ml. of this solution is the equivalent of 0.08 milligram of oxygen when used in standardization of sodium thiosulfate for Winkler titrations.

MANGANOUS SULFATE

Place 480 grams of manganous sulfate, $MnSO_4.4H_2O$, in a large beaker and add 250 ml. of distilled water. Pour the heavy solution into a 1 liter volumetric flask. Continue addition of water to the beaker until all of the manganous sulfate is dissolved. Make up to 1 liter with distilled water. In place of the $MnSO_4.4H_2O$, 400 grams of either $MnSO_4.2H_2O$ or $MnCl_2.4H_2O$ can be used.

ALKALINE-IODIDE REAGENT

Dissolve 700 grams of pure potassium hydroxide, KOH, and 150 grams of reagent-quality, potassium iodide in 750 ml. of distilled water. Cool and make up to 1 liter.

IODIZED ALKALINE-IODIDE REAGENT

Add 10 drops of the stock iodine solution to 500 ml. of the alkaline iodide reagent. Store in a brown bottle. This reagent will be suitable for most samples. However, as the free iodine in this reagent is to nullify the effects of certain interfering substances, the reaction to this reagent should be carefully observed when it is added to the blank in the sample-blank method. If all brown color disappears when the reagent is added to the blank, the free iodine is inadequate to satisfy the interfering substances. If such a sample is found, place several milliliters of the iodized, alkaline-iodide reagent in a beaker and add cautiously small amounts of iodine solution to the reagent until free iodine is present slightly in excess of the quantity to satisfy all the interfering substances, i.e., when the iodized alkaline reagent is added to an untreated sample, a pale yellowish-brown color persists. Use this iodized, alkaline-iodide reagent with fresh samples for both the A and B bottles, and proceed with the analysis. It is important that no more iodine be added to the reagent than is required to produce a pale but persistant yellow-brown color when added to the sample, as excess free iodine will alter the accuracy of the final titration.

Starch Solution

A stable, starch solution as developed in this laboratory (Platner, 1944) has proved very satisfactory for the various titrations, including the Winkler, requiring a starch end-point. This starch solution is prepared by adding approximately 30 ml. of a 20 percent solution of sodium hydroxide to a suspension of 2 grams of powdered potato starch in approximately 350 ml. of distilled water. The hydroxide should be stirred into the starch suspension until a thick, sirupy, almost clear solution is obtained. Put aside for an hour or more and then neutralize with hydrochloric acid using litmus as the indicator. Acidify with 1 ml. of glacial acetic acid. This starch solution is very stable and has been used extensively in both field and laboratory work by the writers.

SULFAMIC ACID REAGENT

Dissolve 4 grams of sulfamic acid in 20 percent (by volume) sulfuric acid to make 100 ml. Store in brown, glass-stoppered bottle.

AMIDOL METHOD

The colorimetric method for the determination of dissolved oxygen with amidol (diaminophenol hydrochloride) by Isaacs (1935) and Gilcreas (1935) although less accurate and dependable than the Winkler method, can be used in some reconnaissance field work to advantage. Amidol in water buffered to pH 5.1 combines with the dissolved oxygen producing a reddish color which, although a mixture of both red and yellow components, can be read quantitatively against artificial standards with reasonable accuracy. The procedure outlined here has been adapted in view of our own findings, from the original method for use in field operations in which equipment must be reduced to the minimum.

Procedure

1. Fill a flat-sided, glass-stoppered, sample-bottle (French

square type) of approximately 70 ml. capacity, with the water to be tested observing the usual precautions in sampling.

2. Remove stopper and add 0.75 gram of finely granular, crystalline sodium citrate. If this is dropped carefully on the surface of the water, the citrate will sink without capturing air bubbles.

3. Drop a very minute quantity of powdered lauryl sulfate onto the surface of the water; use only enough to produce a fine film.

4. Drop 0.25 gram of dry amidol onto this film. Because of the wetting action of the lauryl sulfate, the amidol which otherwise tends to float will sink without capturing air bubbles.

5. Stopper bottle carefully, upend for mixing, and put aside in subdued light for 30 to 45 minutes.

6. Read against artificial standards or color chart.

ARTIFICIAL STANDARDS

The color standards are prepared by using mixtures of cobaltous chloride and potassium dichromate. These can be made up to cover a range from 0 to 14 p. p. m. of dissolved oxygen, but for field and exploratory tests, the writers recommend that only three be carried, namely, the equivalents of 2 p. p. m., 4 p. p. m. and 6 p. p. m. dissolved oxygen, as these values cover the critical range of dissolved oxygen for fish life and if more detailed determinations are required, a Winkler outfit should be obtained.

The stock standard of cobaltous chloride is made by dissolving 476 grams of cobaltous-chloride crystals, $CoCl_2.6H_2O$, and 100 ml. of concentrated hydrochloric acid in distilled water to make one liter. The stock potassium dichromate solution is prepared by dissolving 2.5 grams of potassium-dichromate crystals, $K_2Cr_2O_7$, and 20 ml. of concentrated hydrochloric acid in distilled water to make one liter. Ellis and Ellis (1943) found that the artificial standards prepared from the stock solutions do not have quite the same light transmission curves as do the oxidized-amidol solutions and the amount of dichromate recommended by Gilcreas (1935) in his standards has been reduced slightly.

Mixing 1.5 ml. of the cobalt stock-solution with 1.8 ml. of the dichromate stock solution and making up to 50 ml. with distilled water gives the artificial standard equivalent to 2 p. p. m. of dissolved oxygen; 3.8 ml. of cobalt and 3.0 ml. dichromate made up to 50 ml. with distilled water, the 4 p. p. m. standard; and 6.8 ml. of cobalt and 4.4 ml. of dichromate made up to 50 ml. with distilled water, the 6 p. p. m. standard.

Three bottles of the same type as that used for the sample should be filled with these standards, and the unknown compared with them against a white reflecting surface.

COLOR CHART

Using the artificial standards, or better, the amidol reagents and samples of known dissolved-oxygen content, a color chart can be prepared by painting squares on a white cardboard to match the colors in the standard bottles. The pigments used for tinting photographs or any other good oil or water-color, artist's paint can be used. If water colors are selected, the card must be protected from strong light. These color cards can be prepared for any desired range, but are usable only with the particular type of bottle with which the matching was made. The color card reduces the equipment, as the standard bottles are not needed if the card is carried.

LIMITATIONS

The substances which interfere with the amidol procedure are essentially the same as those interfering with the Winkler method. The tolerances as given by Gilcreas (1935) are: ferric iron, 5 p. p. m.; nitrites, 2 p. p. m.; chlorine, 1.5 p. p. m.; and sulfites, 3 p. p. m. Isaacs (1935) warns that the method is unreliable for salt water or brines as sodium chloride in excess of 0.5 percent will cause the readings to be too high. However, with all of these limitations, the writers have found this method useful in numerous orientation surveys. Under laboratory conditions and with proper equipment, the amidol method can be used successfully for accurate determinations of dissolved oxygen in the photelometer (Ellis and Ellis, 1943).

REAGENTS

Sodium citrate, granular, $Na_3C_6H_5O_7.5H_2O$. — Units of 0.75 gram each are weighed in the laboratory and carried in gelatin capsules. As there is approximately a 25 percent margin of safety for this compound and the amidol in the determination, the weighings need not be too exact.

Lauryl sulfate.—A small bottle of the dry powder will suffice for many determinations as only a very little is required to facilitate the sinking of the amidol.

Amidol (diaminophenol hydrochloride).—Use only the grayish powder, rejecting any which has turned reddish. Units of 0.25 gram are weighed in the laboratory and carried in gelatin capsules. Use as small a capsule as possible so that the amidol will have the minimal exposure to air.

EVALUATION OF DISSOLVED-OXYGEN DETERMINATIONS

The aquatic biologist must evaluate dissolved-oxygen determinations by both biological and chemical standards, that is, both in terms of the requirements of living fishes and of the demands which various pollutants can make upon the available oxygen supply.

The lethal limit of dissolved oxygen for fresh-water fishes is subject to some individual and species variation and to the modifying action of numerous physical and chemical factors. It is not surprising, therefore, that the voluminous literature on this subject contains many apparently conflicting statements due to differences in the conditions under which the fishes were exposed to low oxygen, and to the methods by which the determinations were made. However, if the usual stream and lake complex of aquatic conditions is specified and the water is free from acutely dangerous pollution, certain limits of dissolved oxygen for freshwater fishes can be defined with considerable dependability.

From observations on fishes under field conditions made at several thousand stations in the rivers and streams of the United States over a period of 5 years, during the months of June to September, inclusive, Ellis (1937) states that in general 3 p. p. m. of dissolved oxygen in water at 25° C. is the upper limit of dissolved oxygen at which asphyxia from low oxygen can be expected, and that to maintain in good condition a varied fauna of dissolved oxygen in water at 25° is the upper limit of dissolved oxygen are required. These limits for river and stream conditions have been confirmed by Brinley (1942) and by the United States Public Health Service (1944). They found that fishes, excepting an occasional buffalo, carp, or sunfish, were absent from heavily-polluted waters carrying not more than 3 p. p. m. of dissolved oxygen even during the daytime; that fishes, in polluted water having dissolved oxygen between 3 and 5 p. p. m., showed tendencies to sickness, deformity, and parasitism; and that the fishes were varied, plentiful, and healthy in the less polluted waters with dissolved oxygen not below 5 p. p. m.

Moore (1942), studying the oxygen requirements of fresh water fishes in Minnesota lakes, found that at temperatures between 15° and 26° C. fishes of most species in those lakes died in 24 hours or less if the dissolved oxygen was less than 3.5 p. p. m., and that 5 p. p. m. of dissolved oxygen was not lethal to any fishes examined. Also, during the winter season that 3 p. p. m. dissolved oxygen was not lethal but that fishes of most species died in 48 hours or less if the dissolved oxygen was reduced to 2 p. p. m.

Excepting waters carrying strong pollution, which in itself would kill or would act as an adjuvant to the detrimental action of low dissolved oxygen, it may be stated in general, that dissolved oxygen at levels of 3 p. p. m., or lower, should be regarded as hazardous to lethal under average stream and lake conditions; and that 5 p. p. m. or more of dissolved oxygen should be present in waters, if conditions are to be favorable for fresh-water fishes.

It is not proper, however, to accept water carrying 5 p. p. m. or more of dissolved oxygen as suitable for fishes on that basis alone, for it must be borne in mind that dissolved oxygen is only one of several vital requirements which must be maintained within proper limits if fishes are to thrive. Often the simultaneous alteration of two or more factors toward the unfavorable levels for those factors will produce conditions which, although not definitely unfavorable alone, together will be seriously damaging or even lethal. An increase in acidity and a synchronous reduction in dissolved oxygen (p. 44) is an example of such a synergy.

If pollutants having a high oxygen demand are present in the water, the effects of this demand on the available dissolved oxygen must be determined as it is often possible to predict crises and catastrophies in stream pollution that can be averted by prompt rectification of the cause.

The amount of dissolved oxygen which it is possible for any given water to carry varies directly with the amount of oxygen available and the pressure under which the oxygen is standing, and inversely with the salinity and the temperature of the water.

In most field work, the amount of oxygen can be regarded as constant as pure air carries 20.96 percent oxygen. The partial pressure of the oxygen in the air varies, however, with local barometric fluctuations and with the altitude of the stream or lake. As water supporting fish life will have in general a range between 0 and 35 degrees C. temperature must also be considered. Unless the water is definitely brackish, the effect of a lesser salt content of fresh water on oxygen-carrying power can be disregarded.

In table 1, the values for oxygen saturation of distilled water at various temperatures, pressures, and altitudes, from the air, have been computed from data given by Whipple and Whipple (1911) and the Division of Military Aeronautics (1919). From this table, the expected saturation of distilled water with dissolved oxygen can be found. Stream waters in general carry slightly less dissolved oxygen than distilled water, but the differences are slight, particularly for most mountain streams and lakes.

With the dissolved-oxygen determinations, the expected saturations, the stream flow, and the effluent volume available, computations can be made easily showing how serious the drain on the available dissolved oxygen of the stream by the effluent is at the time or may become during other seasons and under different conditions of stream flow.

OXYGEN DEMAND AND OXYGEN CONSUMED

Many effluents, as sewage, cannery refuse, and paper mill wastes contain substances that are oxidized by the dissolved oxygen in the water either directly or after partial disintegration by bacterial action. These compounds, collectively, at times reduce the dissolved oxygen to critically low levels and can produce sudden, serious, oxygen crises if the water temperature is raised or if stream flow is decreased. Silt and rock powders often complicate the problems produced by the oxygen-consuming materials by flocculating them in layers on the bottom of the stream where they constitute severe hazards to bottom fauna. It is necessary, therefore, to measure the oxygen-consuming power of most effluents containing oxidizable materials. However, it is difficult to make accurate determinations of the oxygen consumed by sewage and other effluents, as these wastes are variable mixtures of many substances that are oxidized at different rates and have different oxygen demands.

The potassium-permanganate method, although subject to very definite limitations, is widely used to measure the amount of oxygen consumed by organic and other oxidizable substances, in various industrial processes, in effluents, and in waters of many sorts. This determination, designated the permanganate number in certain industrial procedures (Edwards and Mackney, 1938), is reasonably accurate for relative comparisons of dilutions of a single product or effluent. However, the permanganate method is not reliable for direct comparisons of different effluents nor in the computation of total oxygen demand, if more than approximate accuracy is required, as the permanganate does not oxidize all compounds with equal efficiency. If these limitations be accepted, the permanganate procedure will supply very useful data concerning the approximate magnitude of the oxygen-demand hazard and the relative amount of oxidizable material present.

METHOD

The procedure outlined is a modification of the basic permanganate method of Tidy (1879).

1. Place 100 ml. of the sample in each of three 250 ml. Kjeldahl flasks and 100 ml. of distilled water into a fourth.
2. Add exactly 10 ml. of 0.125 N potassium permanganate solution ($KMnO_4$) to one sample and to the distilled water blank. To the other two samples, add 15 and 20 ml., respectively, of the 0.125 N potassium-permanganate solution.
3. To each of the four flasks add 10 ml. of 25 percent sulfuric acid.
4. Digest in a boiling water bath for 30 minutes.
5. If a pink color persists in all flasks, proceed; if all color has been discharged, make up a new set using a known dilution of the sample.
6. Remove all four flasks from the bath at the same time and add to each 0.125 N ammonium-oxalate solution to equal exactly in volume the permanganate previously introduced.
7. Adjust the temperature of each flask to 70° C. and titrate at that temperature with 0.125 N potassium-permanganate solution until a pale pink color persists for 30 seconds.

Computation of Results

If the samples receiving the larger amounts of permanganate required proportionately more permanganate for titration, the original permanganate was not adequate for complete action and a new series must be prepared using either a measured dilution of the sample or more potassium permanganate. If the three samples required the same amount of potassium permanganate for titration, deduct the amount of the permanganate required to titrate the distilled water blank from the titration of the sample receiving 10 ml. of permanganate. As the solutions are standardized so that 1 ml. of permanganate solution equals 1 ml. of oxalate solution which in turn is the equivalent of 1 milligram of oxygen if a 100 ml. sample were used multiply the net value of the titration in ml. by 10 and the result will be milligrams of oxygen consumed by 1 liter of the sample or oxygen consumed in p. p. m.

TABLE I.—*Dissolved-oxygen saturation in distilled water exposed to 20.9 percent oxygen gas at pressures and temperatures indicated*

Altitude in feet......	0	1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000	12,000
Pressure in mm.Hg...	760	732	704	677	651	626	602	579	557	536	516	478
0° C...............	14.62	14.08	13.54	13.02	12.52	12.04	11.58	11.14	10.72	10.31	9.93	9.20
1..................	14.23	13.71	13.18	12.68	12.19	11.72	11.27	10.84	10.43	10.04	9.66	8.95
2..................	13.84	13.33	12.82	12.33	11.86	11.40	10.96	10.54	10.14	9.76	9.40	8.70
3..................	13.48	12.98	12.49	12.01	11.55	11.10	10.68	10.27	9.88	9.51	9.15	8.48
4..................	13.13	12.65	12.16	11.70	11.25	10.82	10.40	10.00	9.62	9.26	8.91	8.27
5..................	12.80	12.33	11.86	11.40	10.96	10.54	10.14	9.75	9.38	9.03	8.70	8.05
6..................	12.48	12.02	11.56	11.12	10.69	10.28	9.89	9.51	9.15	8.80	8.47	7.85
7..................	12.17	11.72	11.27	10.84	10.42	10.02	9.64	9.27	8.92	8.58	8.26	7.65
8..................	11.87	11.43	11.00	10.57	10.17	9.78	9.40	9.04	8.70	8.37	8.06	7.47
9..................	11.59	11.16	10.74	10.32	9.93	9.55	9.18	8.83	8.49	8.17	7.87	7.29
10.................	11.33	10.91	10.49	10.09	9.71	9.33	8.97	8.63	8.30	7.99	7.69	7.13
11.................	11.08	10.67	10.26	9.87	9.49	9.13	8.78	8.44	8.12	7.82	7.52	6.97
12.................	10.83	10.43	10.03	9.65	9.28	8.92	8.58	8.25	7.94	7.64	7.35	6.81
13.................	10.60	10.21	9.82	9.44	9.08	8.73	8.40	8.08	7.77	7.48	7.20	6.67
14.................	10.37	9.99	9.61	9.24	8.88	8.54	8.21	7.90	7.60	7.31	7.04	6.52
15.................	10.15	9.78	9.40	9.04	8.69	8.36	8.04	7.73	7.44	7.16	6.89	6.38
16.................	9.95	9.58	9.22	8.86	8.52	8.20	7.88	7.58	7.29	7.02	6.76	6.26
17.................	9.74	9.38	9.02	8.68	8.34	8.02	7.72	7.42	7.14	6.87	6.61	6.13
18.................	9.54	9.19	8.84	8.50	8.17	7.86	7.56	7.27	6.99	6.73	6.48	6.00
19.................	9.35	9.01	8.66	8.33	8.01	7.70	7.41	7.12	6.85	6.60	6.35	5.88
20.................	9.17	8.83	8.49	8.17	7.86	7.55	7.26	6.99	6.72	6.47	6.23	5.77
21.................	8.99	8.66	8.33	8.01	7.70	7.41	7.12	6.85	6.59	6.34	6.10	5.65
22.................	8.83	8.50	8.18	7.87	7.56	7.27	6.99	6.73	6.47	6.23	5.99	5.55
23.................	8.68	8.36	8.04	7.73	7.44	7.15	6.88	6.61	6.36	6.12	5.89	5.46
24.................	8.53	8.22	7.90	7.60	7.31	7.03	6.76	6.50	6.25	6.02	5.79	5.36
25.................	8.38	8.07	7.76	7.46	7.18	6.90	6.64	6.38	6.14	5.91	5.69	5.26
26.................	8.22	7.92	7.61	7.32	7.04	6.77	6.51	6.26	6.02	5.80	5.59	5.17
27.................	8.07	7.77	7.48	7.19	6.91	6.65	6.39	6.15	5.91	5.70	5.48	5.08
28.................	7.92	7.63	7.34	7.06	6.78	6.52	6.27	6.03	5.80	5.59	5.38	4.98
29.................	7.77	7.48	7.20	6.92	6.66	6.40	6.15	5.92	5.69	5.48	5.28	4.89
30.................	7.63	7.35	7.07	6.80	6.54	6.28	6.04	5.81	5.59	5.38	5.18	4.80

NOTE.—Computed from data given by Whipple and Whipple (1911), and Division of Military Aeronautics (1919).

LIMITATIONS OF METHOD

It is necessary to run a reagent blank using distilled water with every set of samples for as pointed out by Koltoff and Sandell (1938), some of the permanganate solution is decomposed by the sulfuric acid and unless proper deduction be made for this factor, the oxygen consumed value will be too high.

As noted by Edwards and Mackney (1938) in their studies of paper pulps, there is a minimal ratio of permanganate to the quantity of material to be oxidized which must be maintained if complete action by the permanganate is to be obtained. This ratio varies with different oxygen-consuming compounds. Platner and Meyer (1945) in our laboratories have recently tested permanganate on numerous organic compounds and polluted waters and find that a ratio of three parts permanganate to one of the oxygen-consuming substance is desirable for the complete action of the permanganate on the various materials which might be expected in the common effluents and polluted waters. An excess of permanganate beyond this 3 : 1 ratio did not affect the end results. However, the amount of permanganate required for effluents and polluted water to constitute a 3 : 1 ratio cannot be predicted in advance of the test. Consequently three samples are treated with different amounts of permanganate (p. 26) and the final titrations compared. If these titrations are not the same, it is evident that more permanganate should have been used and a new series must be prepared.

These observers confirmed previously reported findings that in general nitrogenous organic compounds are not so readily oxidized by permanganate as those containing no nitrogen, and that certain organic compounds as acetic and succinic acids are not attacked by the permanganate solution in the procedure given here. Using the same quantities of test substances with dextrose as a standard, the oxygen consumed from permanganate by salicylic and sulfanilic acids greatly exceeded that of dextrose. Urea, citric, tartaric, and lactic acids consumed less oxygen than dextrose; urea removing only about 30 percent as much oxygen as dextrose. These observations point out the unreliability of direct comparisons of effluents in terms of oxygen consumed from potassium permanganate.

REAGENTS

Ammonium oxalate, 0.125 N solution. — Dissolve exactly 8.881 grams of ammonium oxalate, $(NH_4)_2C_2O_4.H_2O$, in distilled water to make 1 liter. This solution is not dependable for more than two or three weeks. Keep in a brown glass-stoppered bottle. One ml. is the equivalent of 1 milligram of oxygen in the final titration.

Potassium permanganate, 0.125 N solution. — Dissolve 4 grams of potassium permanganate, $KMnO_4$, in distilled water to make 1 liter. Put aside in a brown, glass-stoppered bottle for at least 24 hours. Carefully decant or siphon (all glass) the clear fluid into a second brown, glass-stoppered bottle, rejecting the turbid fluid and brownish precipitate in the bottom of the first bottle.

Standardize the solution by adding 10 ml. of the permanganate solution to 100 ml. of distilled water and 10 ml. of 25 percent sulfuric acid previously mixed in a Kjeldahl flask. Digest in a boiling water bath for 30 minutes. Add 10 ml. of 0.125 N ammonium oxalate solution and then permanganate solution cautiously until a pale pink color persists for 30 seconds.

Return flask to water bath and raise temperature to almost 100° C. Remove from water bath and add at once exactly 10 ml. of the ammonium oxalate solution. Cool to 70° C. and titrate with the permanganate solution until a pale pink color persists for 30 seconds. From this titration, note the ratio of permanganate to oxalate and adjust the permanganate solution to equal exactly the oxalate solution volume per volume.

Protect standardized permanganate solution against any contamination, particularly dust and organic material.

Sulfuric acid, 25 percent by volume. — Add cautiously 25 ml. of concentrated c.p. sulfuric acid to 75 ml. of distilled water.

SPECIFIC CONDUCTANCE

Natural waters normally contain various quantities of dissolved salts, chief among which are the chlorides, sulfates, carbonates, and phosphates of sodium, potassium, calcium, and magnesium. Usually the total amount of these salts is small. However, in waters polluted with brine, oil-well waters, and chemical wastes, dissolved salts, acids, and alkalis often rise to levels dangerous to aquatic life. Specific conductance offers a quick and convenient method for the determination of these substances collectively, that is, the degree of electrolyte pollution, and a means of following this pollution, for the conductance of an electrolyte in solution is almost directly proportional to the ionic strength of that solution whether it is a natural water or pure solution (Coin, 1943), and the total conductivity of a given water is equal to the sum of the several conductivities resulting from the various ionizable salts present.

Although determinations of conductance are valuable aids in pollution studies, there are many factors which must be considered in the proper interpretation of the data. The conductance of aqueous solutions of ionizable compounds varies with the particular compound, the concentration, the degree of ionization, and the temperature. In general, the specific conductance (the reciprocal of the resistance in ohms of a column of the solution one centimeter long and having a cross section of one square centimeter, at a specified temperature) decreases with dilution in contrast to the equivalent conductance (the specific conductance multiplied by the number of milliliters of the solution containing one equivalent weight of solute) which increases with dilution up to a maximum (Davies, 1940).

The conductances of various compounds in aqueous solution differ markedly. For example, a solution carrying 10 milli-equivalents of hydrochloric acid per liter at 18° C. has an equivalent conductance of 368.1 mho which is almost 40 times that of the same concentration of ammonium hydroxide, 9.66 mho. Specific ions in solution also show differences in equivalent conductance. An aqueous solution carrying 10 milliequivalents of sodium ions per liter at 18° C. has a conductance of 4.3 mho; of hydroxyl ions, 172 mho; and of hydrogen ions, 314 mho (Hodgman and Holmes, 1941). It is evident that a mixture of different elements, compounds, or both could result in an infinite number of different conductance values depending on the elements or compounds present, the quantity of each, and the ratio of any one to any or all of the others.

Certain relationships exist that are helpful in the interpretation of these data. Each ion in solution at infinite dilution has a certain equivalent conductance at a specific temperature. According to Kohlrausch's law (1905) for ionic conductance at infinite dilution, the equivalent conductance is equal to the sum of the conductances of the positive ion and the negative ion at a given temperature. Gunning and Gordon (1942) have shown that this law is obeyed at all temperatures. Therefore, if the solution is pure and the conductance is known, the concentration can be calculated. However, in waters containing many different salts in varying concentration not always at infinite dilution, no such calculation is possible.

Conductance also varies with the temperature, for as the temperature increases, the mobility of ions increases, thereby raising the conductance of the aqueous solution. Physical chemists often use a two percent increase per degree as a correction factor (Hitchcock, 1940; Bull, 1943). This usage is not strictly valid as, for example, the equivalent conductance of a solution of acetic acid (10 milliequivalents per liter) rises only about 0.9 percent per degree as compared to an increase of about 2.5 percent per degree for potassium chloride (between 18° and 100° C.).

Even though the temperature remains the same, the conductance of a compound in solution varies as concentration increases, but not always at the same rate or even in the same direction. Magnesium sulfate, a common constituent of many natural waters, causes an increase in the conductance when dilution is high, but when the concentration is 3 to 4 equivalent weights per liter or more, a maximum is reached beyond which the conductance decreases even though the concentration of the electrolyte is increased (Ullyott and Ilgaz, 1942).

Recently Gopal (1943) found that the specific conductance of the solution of most electrolytes exhibits a maximum at about 20 to 30 percent (composition expressed in terms of equivalents). This maximum was observed to occur at almost the same equivalent concentration for solutions containing the same anion, but different cations, apparently because of the change in entropy of ions on hydration. These data help explain an apparently paradoxical finding that occasionally is encountered in water studies in which the conductance of a particular water not only does not rise with a rise in temperature, but actually falls.

The conductance of aqueous solutions of crystalloids is frequently affected by the presence of colloids and suspended material which may or may not be conductors. In high dilution, colloidal solutions are relatively good conductors. However, in less dilute solutions, the conductance coefficient falls off sharply. Most soaps and other detergents act similarly (Alexander, 1944).

Suspensions or partial solutions of celluloses, starches, and other carbohydrates dissolved in electrolyte-free water conduct very little better than distilled water. However, as some of the breakdown products of many carbohydrates are ionizable the conductance may increase on disintegration of these carbohydrates in polluted water.

Suspensions of cellulose, various rock powders, clays, and even living cells all of which are relatively poor conductors obstruct the movement of ions, thus decreasing conductivity of the suspension. Studies on non-conductors have shown that the greater the suspension, the greater the resistance (Velick and Gorin, 1940).

As live cells act as non-conductors at the frequency commonly used (1,000 per sec) for the determination of conductivity in water pollution studies and as dead cells are more permeable, hence better conductors, care must be used in the interpretation of data on waters containing large quantities of any living or dead organisms. The specific conductance of protoplasm of paramecia is 0.0068 reciprocal ohms (Alexander, 1928) which is greater than the specific conductance of many natural unpolluted waters. Hence, if a sufficient quantity of dead protozoans or other plankton organisms is present, the conductance of the water may be changed measurably.

In general, excepting in plains and desert regions, the specific conductance of inland fresh waters supporting a good fish fauna lies between 150 and 500 $\times 10^{-6}$ mho at 25° C. Mountain streams flowing through granite areas may have even lower conductance values. However, the little creeks and even the rivers flowing through western plains and desert areas often carry large quantities of alkaline salts especially after heavy rains, which ionizable material often carries the specific conductance to 2000 $\times 10^{-6}$ mho or more at 25° C.

Polluted waters are not as predictable and constant as the natural streams with regard to specific conductance. The variations due to the presence of pollutants depend chiefly on three main conditions; namely, the type of waste whether ionizable, colloidal suspended material, or a mixture; the salt concentration of the stream itself, especially the buffer systems present; and the amount of waste entering as compared to the stream flow.

METHOD

Apparatus

The determination of specific conductance is based on the Wheatstone bridge in which a variable resistance can be adjusted so that it is equal to the resistance of the unknown solution between two platinized electrodes of a standardized conductivity cell.

Various means of detecting a balance of the bridge have been used, such as the galvanometer, electron ray tube, sensitive meters, and telephone receivers, the latter having been found very satisfactory and sturdy for field use, yet having adequate sensitivity. It is suggested that earphones especially constructed to receive the 1,000 per second oscillations from the microhummer be used for maximal efficiency, as other types of phones give some difficulty as the end-point is approached. If more accurate end-points are desired in the laboratory where fragility of apparatus and lack of mobility is of less importance, an audion tube may be used for the alternating current source with two or more amplification stages connected to an electron ray tube or a sensitive galvanometer. If a telephone receiver is used, added sensitivity can be attained by connecting a stethoscope to the earphones.

Special apparatus for conductivity measurements can be purchased from supply houses. However, units have been built in this laboratory which are less expensive and quite satisfactory especially for field work. In this apparatus two sides of the bridge are composed of a good-quality, 100-ohm, resistance unit so that the proportion $\frac{R_1}{R_2}=\frac{R_3}{R_4}$ results in $R_3 = R_4$, since R_1 and R_2 are each 100 ohms in this apparatus.

The variable resistance consists of a standard box capable of measuring 1 to 10,000 ohms. In series with this box a switch connects a single 10,000 ohm resistor so that a maximum of 20,000 ohms can be thrown quickly into the circuit.

Alternating currents of many different frequencies have been used in the determination of specific conductance; however, to minimize electrode heating, polarization, and other electrical difficulties and yet produce an easily detectible hum having a pitch within the optimal range as regards hearing acuity, the preferred rate for use in analyzing most water has been found to be 1,000 per second. For this purpose a standard microhummer powered by four ordinary dry cells (1½ volts each) in series has proved satisfactory. To minimize difficulties due to heating, a maximum of ten seconds should be allowed for making a reading.

Conductivity cells of the dip type are recommended for convenience in cleansing and rinsing. One cell for high, and one for low conductance are required. These cells are so connected with a two-way switch that either can be put into use almost instantly. With these two cells and a variable resistance of 20,000 ohms, the conductance can be determined over a wide range from ordinary distilled water to water carrying a high concentration of salts. The cells may be glass, or if greater durability is desired, they may be made of lucite as described by Howard (1939).

As conductance varies so much with temperature changes, even small temperature fluctuations during the reading must be avoided. Temperature changes are responsible for the greatest error in the determination of conductance of solutions. Therefore, a good thermometer calibrated to 0.1° C. should be placed in the sample with the conductivity cell and the temperature read very carefully at the time the conductance is measured.

If the apparatus has been assembled as described and care exercised to assure good electrical connections, proper chemical cleanliness, and temperature control, excellent results can be realized both in the laboratory and in the field.

Further details concerning the theory of conduction of electricity through electrolytic solutions, and the actual measurement of conductance can be found in most texts on physical chemistry, as Davies (1940), Hitchcock (1940), Kolthoff and Laitinen (1941), and Bull (1943). For detailed discussion of the proper types of apparatus, refer to Taylor and Acree (1916), Washburn (1916), Kendall (1916), Sousa (1937), Polyakov and Ivanov (1938), Hovorka and Mendenhall (1939), and Luder (1940). A thorough discussion of the measurement of the conductance of electrolytes with special reference to extreme accuracy is presented by Shedlovsky (1932), Jones and Bradshaw (1933), Ender (1937), and Gunning and Gordon (1942).

Temperature Correction

As the value of conductance in pollution studies lies chiefly in comparisons of conditions before and after entrance of an effluent into a stream, the elaborate method for simultaneous temperature and conductance readings given by Ullyot and Ilgaz (1942), in which the conductivity cell and a thermocouple are lowered simultaneously to various depths, is unnecessary. Sampling with a Foerst apparatus has proved both more practical and sufficiently accurate for most field studies of specific conductance as the values are reduced to 25° C. for comparison. However, the conductance should be read as soon as possible after the sample is taken to avoid loss of carbon dioxide and to minimize other changes which might take place on standing.

Two or more readings on specific conductance should be taken on each sample, preferably above and below 25° C. The change in conductance per degree can then be computed and the value at 25° C. established.

Standardization of The Conductivity Cell

Before the conductivity cell can be used, the electrodes must be platinized and the cell then standardized against a solution of known specific conductance to determine the cell-constant for that particular cell. If the cell is properly handled, one platinization and standardization will suffice for days or even weeks.

Platinizing The Electrodes

1. Three grams of chloroplatinic acid are dissolved in 10 ml. of distilled water to which 20 mg. of lead acetate are added.
2. Clean electrodes in standard sulfuric acid bichromate cleaning solution. Rinse thoroughly in several changes of distilled water.
3. Place electrodes in the solution of chloroplatinic acid and lead acetate.
4. Connect the electrodes with two dry cells (1½ volts each) in series.
5. Reverse direction of the current once a minute for six minutes.
6. Repeat (4 and 5) in dilute sulfuric acid (about 10 percent) to remove chlorine.

7. When not in use keep the cell in pure distilled water, for if the electrodes once become dry, they are very difficult to wet again.

Standardizing The Electrodes

1. Prepare N/50 potassium chloride solution (N/10 or N/100 may be used). It has been suggested recently that benzoic acid be used instead of potassium chloride for the standard electrolyte in the calibration of conductivity cells, especially of low cell-constant (Ives and Sames, 1943).
2. Submerge electrode 1 cm. below surface of this solution of potassium chloride or benzoic acid.
3. Establish cell and fluid at a constant temperature (25° C.).
4. Determine the resistance (R) in the variable-resistance box which gives minimum hum as heard in the phone.
5. From tables determine specific conductance (k) of N/50 potassium chloride. This value is generally given as 0.002765 at 25° C.
6. Cell constant determined from $1/R\ C = K$; or $C = K/1/R$.
7. Restandardizing necessary only when electrodes have to be replatinized.

Preparation of Sample

If large amounts of plankton, detritus, or suspensoids are present, the sample should be filtered through absorbent cotton. If the water is reasonably free from suspensoids of any type, it can be used as taken from the sampler. Effluents containing much free acid or alkali can damage the electrodes. The readings for such effluents should be made as quickly as possible and the electrodes rinsed promptly with distilled water.

Calculation of Results

The specific conductance of an unknown solution is calculated by multiplying the reciprocal of the resistance as read from the variable-resistance box by the cell constant. This gives the specific conductance in reciprocal ohms or mho. As these values are usually very small fractions of one mho for natural and even polluted waters, the results are expressed for convenience exponentially, that is 10 to the -6 power. Since most of the work has been reported on solutions at 18° and 25° C. and since room temperatures in which experiments are carried, and as many streams in summer have temperatures within that range, the temperature selected as standard for pollution studies is 25° C. The specific conductance, therefore, is reported in this fashion: 140×10^{-6} mho at 25° C.

HYDROGEN-ION CONCENTRATION (pH)

GLASS-ELECTRODE

The glass electrode has practically superseded all other forms of electrodes, and also the indicator dyes for accurate determinations of hydrogen-ion concentration (pH), that is, relative acidity and alkalinity. Any of the several standard makes of glass electrode pH meters can be used. These instruments differ in details of construction although not in principle, and the manufacturers' directions and precautions must be studied and mastered for each different model.

The essential part of the pH meter is a thin walled bulb made of a special low resistance glass and filled with 0.1 N hydrochloric acid. On the surface of such a bulb, a very small E.M.F. is developed whenever the bulb is placed in a solution, and this E.M.F. is proportional to the hydrogen-ion concentration of the solution. This phenomenon was described by Haber and Klemensiewicz (1909) and further studied by Hughes (1922) and Horovitz (1923). It was applied to the estimation of the pH of solutions independently by Steiger (1924) and Brown (1924).

The remainder of the instrument consists of a reference electrode, usually a concentrated KCl-calomel half cell, to complete the circuit, and a vacuum-tube potentiometer. The potentiometer is wired so that when its knob or dial is in proper position to indicate the pH of the sample in which the electrodes are immersed, the needle of the ammeter will behave in a specified manner, i.e., remain at "O" position in meters of some patterns or cease deflecting in meters of certain other designs.

Compensation is made for the temperature of the sample in the process of adjusting the working current before the pH reading is made, the exact procedure depending upon the type of meter used. The position of the potentiometer indicator from which the pH reading is made must be checked frequently. This is usually done by placing a buffer solution of known pH in the cup with the electrodes and adjusting the potentiometer knob or dial until the instrument gives the correct reading. A solution of any of several buffer compounds can be used for this purpose, but as the 0.05 M solution (10.207 grams per liter) of potassium acid phthalate has an acidity of pH 3.97 and is very stable that compound is recommended.

The limitations and necessary precautions to be noted in the use of the glass-electrode instruments are emphasized in the instructions supplied by their makers, but three are repeated here as they are vital to successful operation in the field. The two electrodes must be kept scrupulously clean, and must be attached by the proper cables to the correct poles of the potentiometer; the cables of the terminals and electrodes must be clean and bright for good electrical contacts; and fresh concentrated potassium chloride must be flushed through the reference calomel electrode frequently to maintain contact with the sample and to eliminate contamination from previous samples.

Painstaking and ample rinsing of both electrodes is imperative. The electrodes should be rinsed once or twice with the sample to be tested before the cup is filled with the sample and the electrodes arranged for the reading. If a series of dilutions of the sample is to be run, it is often well to progress in order from the weakest to the strongest of the series. On completion of a series of determinations, the electrodes should be rinsed very carefully with distilled water and kept in distilled water when the instrument is not in use.

A few other suggestions may be made concerning the use of the glass-electrode pH meter in field studies of water quality. Although adjustment is made to correct the pH readings for temperature, it has been found advisable to avoid placing the instrument in direct sunlight or in a position where it will receive intermittent sunlight and shade, as fluctuating temperature values may result.

Free carbon dioxide in the sample will cause an annoying "slipping" of the pH readings because the hydrogen-ion concentration changes in a matter of minutes when the carbon dioxide leaves the sample. Likewise certain rapidly oxidizable substances, as ferrous iron, found in some waters cause rapid changes in pH reading if these substances are allowed to take up oxygen from the air. In such cases special care should be taken, first in collecting the sample which should be placed in the sample bottle without agitation or exposure to air and stoppered without the entrainment of air bubbles (p. 3), and the pH reading should be made as quickly as possible. If a series of samples containing such substances is to be run, it is advisable to make all the readings with a short but constant time interval between the opening of the sample bottle and the reading of the pH meter.

Another more accurate device is the constant-flow, glass electrode which is connected with the sample bottle so that a slow stream of the water is siphoned continuously through a special cup receiving the two electrodes. This arrangement automatically rinses the electrodes and because of the large volume of the sample moving past the electrodes will give less change in the pH of the material and truer readings.

The glass-electrode pH meters are portable instruments but to carry such an instrument successfully and without breakage on an extended field trip requires special care. The instrument after the electrodes and sample cup have been removed can be packed safely in a strong wooden chest lined with sponge rubber padding to reduce vibration and to take up the jar of any sudden impact. The concentrated KCl-calomel electrode is usually provided with a rubber boot which can be slipped over the end of the electrode when the meter is not in use. With this boot or cap in place, the electrode can be packed with cotton wool in a small box.

The glass electrode is more difficult to house for transportation because the glass membrane must be kept wet with distilled water when not in use. Some manufacturers provide a tube suitable for this purpose. However, a carrying bottle in which the glass electrode can be carried with safety can be made by using a small wide-mouthed jar packed with well-washed absorbent cotton and filled with distilled water, leaving a central well into which the electrode can be placed, and fitted with a split rubber stopper that will receive the top of electrode and hold its tube in such a position that the bulb will be free of any contact with the glass bottle. Any shock or vibration will be taken up by the wet cotton. Of course, provision must be made to carry the electrode bottle in an upright position.

The glass electrode as currently supplied by manufacturers has an accurate working range from pH 0.0 to pH 9.0 and if salts of sodium, lithium, and potassium are not present, the alkaline range may be extended to between pH 11 and pH 14 without correction. However, above pH 9.0 sodium salts, if present in sufficient quantity, cause a salt error or sodium-ion error; and similar salt errors but of much less magnitude are produced by salts of lithium, potassium, ammonium, calcium, and barium. During the past few years glass electrodes made from other types of glass having smaller salt errors have been developed by various manufacturers (Chem. and Metallurgical Eng., 1940). Correction curves for the salt errors of the particular glass electrode are usually supplied with the instrument.

Fortunately, these sodium-ion and other salt errors need not be considered in studies of most natural waters as these waters are generally less alkaline than pH 9.0, do not carry sufficient sodium salts to cause appreciable error, and are rarely above 25° C., beyond which temperature the salt errors become more pronounced. However, in dealing with waters which are more alkaline than pH 9.0 and at the same time are heavily polluted, or with strongly alkaline chemical effluents, the correction tables should be consulted. The bulb of the glass electrode can be injured by strong acids or solutions more alkaline than pH 10, so exposures to such solutions should be made as short as practical.

COLORIMETRIC DETERMINATIONS OF HYDROGEN-ION CONCENTRATION

Hydrogen-ion concentration can be determined in many waters with fair accuracy by the use of dyes. In some waters, however, only approximate or even erroneous pH values can be obtained with them. The colors of these dyes not only vary with the pH but are subject to salt and protein errors if either of these substances is present in appreciable quantities; also, the dyes are modified as to shade by many specific compounds and may fade unexpectedly. Besides, the terminal pH values marking the extremes of the range of any given dye may vary somewhat with chemical conditions so that the standardization of the dye for a high degree of accuracy is not possible if dye is to be used with waters of unknown composition. Again, there is often a large personal error in matching colors. Consequently, the glass electrode should be used whenever possible. With all of these limitations, however, indicator dyes have a place in field work at least as emergency equipment, if the data obtained by their use are properly evaluated.

Indicator dyes are compounds, the colors of which can be correlated with the hydrogen-ion concentration of the solution in which they are dissolved. For each of these indicators there is a pH range through which the color of the dye in solution is progressively intermediate between the color of the completely acidic phase and that of the completely alkaline phase. As this pH range, between the acidic and the alkaline colors, is rather narrow in the case of most indicators, various series of pH indicators the ranges of which overlap, have been selected by workers in this field. These acidimetric and alkalimetric color reactions of indicator dyes have been applied to the estimation of pH in several ways but because neither permanent standards nor buffer solutions are required, the Gillespie tube method is preferred for field studies of water quality.

Gillespie (1920) assumed that the precise color of a solution of an indicator dye is due to the percentage of the dye in the acid phase plus the percentage in the alkaline phase and that the same color may be produced if the identical percentages of the same amounts of dye are placed in separate containers and viewed by light passing through the two solutions. Pairs of matched tubes are prepared, therefore, one of which contains acid and the other alkali sufficient to produce the color dissociations and development of the complete acidic and alkaline phases. The percentage of dye added to the acid and alkali is varied mathematically so that the colors of the pair of tubes, that is, one in the acidic phase and one in the alkaline phase, when viewed together exactly duplicates the color of the same total quantity of dye in a buffer solution of known pH. This relationship between percentages of acidic and alkaline dissociations and the resultant hydrogen-ion concentration of aqueous solutions has been worked out for a large number of dyes.

Gillespie (1920) favored the use of seven indicator dyes covering a range from pH 3.10 to pH 9.75 but in actual field operations, the authors have found three dyes, brom-cresol purple, bromthymol blue, and cresol red, sufficient for most waters for which colorimetric determinations were feasible. These three dyes cover, collectively, a range from pH 5.2 to pH 8.8. Occasionally, bromcresol green and thymol blue (alkaline range) have been added, extending the range from pH 3.8 to pH 9.6. However, as strongly acidic or strongly alkaline waters and many effluents usually contain substances which render colorimetric determinations unreliable, if strongly acidic or alkaline samples are found, it is better to use indicator paper for a quick approximate determination pending an accurate determination with the glass electrode.

METHOD

The paired-tube method used by the authors is essentially that described by Gillespie (1920) with certain modifications which field tests have proved desirable.

Tubes

Select 26 test tubes or culture tubes (15 × 1.5 cm. is a very satisfactory size) of clear, colorless glass for a matched series, i.e., the tubes should be free from flaws and uniform in dimensions so that when exactly 10 ml. of distilled water are placed in each tube, the height of the columns will not vary more than 3 to 4 millimeters. Each tube should be provided with a rubber stopper previously boiled in sodium carbonate and subsequently in distilled water to remove soluble material which might affect the dyes. The tubes are mounted in a wooden rack having two parallel rows of 13 slots or holes so that the tubes stand in pairs. With the rack facing the operator and beginning on the left, the first eleven tubes of the front row are labeled and numbered consecutively from 10 to 0, inclusive, and the comparable tubes of the back row from 0 to 10, inclusive, so that the sum of the values on the two tubes of any pair equals 10.

Comparator Block

This block is easily made in any laboratory shop or can be purchased from supply houses. In a block of fine-grained wood, 3 inches wide, 4 deep, and 4 high, drill 6 holes vertically in 2 rows of 3 so these holes will be perpendicular to the base of the block and will form 2 lines parallel with the 4-inch sides of the block. The holes should be about 1/16-inch larger than the outside diameter of the tubes to be used in them and should be drilled entirely through the block. Measure up about 3/4-inch from the bottom of the block on the 3-inch front and drill two holes, each about three-fourths of the diameter of the tubes, through the block so that each hole will intersect the 3 holes of the vertical series on that side at right angles. Tack a piece of plywood on the bottom of the block to prevent the tubes from falling through when placed in the vertical holes and the comparator is ready for use. The samples and the standards are read through the 2 horizontal holes and the block should be held so that the light entering the horizontal holes and passing through the tubes is reflected from a white surface.

Standards

From a burette measure exactly 5 ml. of distilled water into each of the labeled tubes. To the tubes in the front row add from a dropper the number of drops of the indicator dye selected as indicated by the figure on the label of the tube. Repeat for the back row. With a second dropper delivering the same sized drops, add to each tube of both series a sufficient number of drops of distilled water to total 10 when counted with the number of drops of dye already in the tube. To the tubes in the front row, add the amount of acid indicated for the dye chosen (table 2) and to those of the back row, the proper amount of alkali. Stopper the tubes and rotate until the fluids in each are thoroughly mixed.

Label the extreme left-hand pair, the 10-0 pair, with the pH value marking the end of the acid range of the dye, for in this pair the front tube carries 10 drops of the dye in the acidic phase and the back tube contains no dye, only distilled water. Similarly, label the extreme right pair with the pH value marking the end of the alkaline range of the dye. Take the difference between the two, i.e., the total pH range of the dye (table 2), and divide by 10. To obtain the pH value of any pair of standard tubes, multiply this figure by the number of drops of dye in the tube in the back row, i.e., the alkaline row and add the value obtained to the pH value marking the acid limit of the dye. The pH value for each pair of tubes should be computed and the tubes so labeled.

Standards prepared in this manner will be usable for several days or longer if properly protected from sunlight or other strong light and the action of bacteria.

For more accurate measurement of the dye both in the preparation of the standards and in the subsequent test of the unknown, a 1-ml. pipette graduated in 0.01 ml. is preferable to the common droppers which vary considerably in bore. If a graduated pipette is used, substitute 0.05 ml. for one drop.

The method of computation by which the pH value of the intermediate standards is established as given above is quite empirical, but accurate enough for the general type of field work to which this method can be applied. However, if greater accuracy is desired and if the conditions under which the dyes are to be used warrant, the dissociation curves of the several dyes can be applied and a more accurate pH value predicted for the particular drop ratio used. This can be checked still further by standardizing with the glass electrode. It is doubtful if all of this additional standardization is justified in most field work where indicator dyes can be used advantageously.

THE DETERMINATION

Place exactly 5 ml. of the sample in one of the empty tubes of this series. With the same dropper used for the dye in preparing the standards, add 10 drops of the dye to sample, stopper, rotate until mixed, and place in a comparator block in front of a tube filled with distilled water. Into the adjacent holes in the comparator block, place successive pairs of standards until the color in the sample is matched. The pH of this pair of standards equals the pH of the sample.

If the sample is turbid or colored, a third tube filled with untreated sample water must be placed behind the standard tubes, and a second tube of distilled water behind the sample carrying the indicator dye, to compensate for the color or turbidity of the sample. In this case the reading is made through three tubes instead of two.

CHOICE OF DYES

In table 2, seven dyes are listed which the authors have found useful in field water studies for pH measurements. Many other dyes have been used in specific tests but these seven have proved satisfactory within the limitations of this type of determination. Stock solutions of these dyes are carried in the field with a set of tubes and comparator and provide an emergency method for pH readings which on numerous occasions has been very helpful.

REAGENTS

Stock solutions of dyes. — Indicator dyes for water studies are currently prepared either as an aqueous solution of the sodium salt of the dye or as the alcoholic solution of the untreated dye. The aqueous solution of the sodium salt gives a more accurate dye in that the solution is essentially neutral and the drops of dye when added to the sample are less apt to modify the pH if the sample is poorly buffered.

Aqueous solution of dye. — Grind 0.1 gram of the dye in an agate mortar with the amount of 0.01 N sodium hydroxide indicated in table 2, and when completely dissolved, make up to 50 ml. with distilled water. This 0.2 percent stock solution should be kept in a small brown, glass-stoppered bottle and diluted with distilled water as needed to the value given in table 2 (Clark, 1928).

Alcoholic solution of dye. — Dissolve 0.1 gram of the dye in a few milliliters of 95 percent ethyl alcohol and make up to 100 ml. with additional 95 percent alcohol. This 0.1 stock solution should be kept in a small brown bottle and diluted as needed. The alcoholic solution is acidic due to the composition of the dye so when the dilution with water is made, the dye should be brought to within a few milliliters of the diluted volume and 0.2 percent NaOH solution dropped in cautiously while the bottle is being swirled until the acid color just begins to change. The remaining water necessary to complete the proper volume for the dilution is then added.

Sodium hydroxide. — A 0.2 percent solution for developing the alkaline color in the standard tubes is made with sufficient accuracy using ordinary stick or pellet sodium hydroxide.

Sodium hydroxide, 0.01 N solution. — If used in preparing the stock solutions of the indicators it should be accurately made, free from carbonates, and standardized against 0.01 N sulfuric acid using methyl orange indicator.

Hydrochloric acid solution 0.05 M. — Used to produce the acidic phase, it is satisfactorily prepared by diluting 1 ml. of concentrated hydrochloric acid (specific gravity 1.19) to 240 ml.

Diacidic potassium phosphate (H_2KPO_4). — 2 percent solution is used to produce the acidic phase when cresol red or thymol blue (alkaline range) are used because these dyes are altered by hydrochloric acid.

SPOTTING TESTS FOR pH

Papers

Several kinds of pH paper are available with color standard charts attached to the containers for rapid determinations of pH in the field. These papers are often very useful and are carried as part of our field equipment for reconaissance and orientation tests, as collectively these papers cover the range from pH 1 to pH 14 rather satisfactorily.

In using indicator papers, it must be noted that the surface or finish of the paper will influence the validity and speed of the test. If the impregnated paper has a hard finish, that is if it contains sizing, it will be slow in registering the color change of the solution with which it is wetted because the sizing usually acts as a buffer. If a soft-finish paper, like filter paper stock is impregnated with the dye, there is no such buffer effect and the color of the dye will develop promptly. However, the central wet portion of this type of test paper must be matched with the color standards and the color of the portion which is merely dampened by capillarity at the end of the wet area disregarded, for at the junction of the wet and dry portions of the paper, capillarity will draw up and concentrate some of the dye so that a ring of brighter color, often of slightly different shade will develop at the junction point. The color of this ring or line at the junction point is disregarded as it will not give a true reading.

The dyes with which the papers are impregnated are subject, of course, to the same general errors when used in the paper form as when used in the solution form, namely salt, protein, and temperature errors, all of which have been discussed previously. In addition, however, the wet paper can easily be disturbed and give a spurious pH reading in consequence, by the presence of vapors and gases in the surrounding air. If pH paper is used for spotting tests, care must be taken to avoid breathing directly on the wetted paper because the carbon dioxide in the exhaled air may render the reading more acidic than it should be. Similarly, tobacco smoke, fumes from chemical operations, and exhaust gases from engines and other mechanical devices must be avoided when pH paper is used.

Dye Mixtures

Various supply houses have prepared mixtures of indicator dyes for quick approximate determinations of pH in spotting plates of glass or porcelain. These dyes are mixtures of two or more indicator dyes covering different parts of the pH range, and the combined color, therefore, of the two dyes in different phases of dissociation often gives a series of colors quite different from those of the component indicator dyes. The manufacturers of these all-purpose pH dyes supply small color charts with their products which can be used for rapid approximate pH determinations in the field. The dye mixtures have all the disadvantages of their component dyes and, in addition, the disadvantage of additional color shades to be read by the observer. Consequently, the personal error is often quite high in the use of these mixtures. However, for some types of field work where it is not feasible to carry other equipment, these indicator mixtures fill a useful place.

EVALUATION OF pH DETERMINATIONS

In water-quality studies, it must be borne in mind that the hydrogen-ion concentration is the resultant of several, often many, factors some synergistic, some antagonistic. It is not unusual, therefore, to find that two waters, although carrying different loads of dissolved materials, have identical hydrogen-ion concentrations. As carbon dioxide and the carbonates and sulfates of calcium and magnesium, all normal components of most stream and lake waters, collectively cause marked changes in the pH of the water in which they are dissolved, if the amounts of any or all of these compounds in solution vary even slightly, it is not surprising that unpolluted waters supporting good fish fauna may vary in hydrogen-ion concentration from pH 6.0 to pH 8.7.

TABLE 2.—*Indicator dyes*

Indicator	Range, pH	Ml. 0.01 N NaOH to dissolve 0.1 gm. dye	Amount and solution used to produce acidic phase of dye	Percentage of dye used for 10 drops dye in 5 ml. of water
Brom-phenol blue	3.0-4.6 [1]	14.9	1 ml. 0.05 M HCl	0.02
Brom-cresol green	3.8-5.4 [2]	14.3	1 drop 0.05 M HCl	0.02
Brom-cresol purple	5.2-6.8 [3]	18.5	1 drop 0.05 M HCl	0.02
Brom-thymol blue	6.0-7.6 [3]	16.0	1 drop 0.05 M HCl	0.02
Phenol red	6.8-8.4 [3]	28.2	1 drop 0.05 M HCl	0.01
Cresol red	7.2-8.8 [3]	26.2	1 drop 2 percent H_2KPO_4	0.01
Thymol blue (alkaline)	8.0-9.6 [3]	21.5	1 drop 2 percent H_2KPO_4	0.02

The alkaline phase of the indicators is produced by adding 1 drop of 0.2 percent sodium hydroxide to the 5 ml. dye standard, excepting in the case of thymol blue (alkaline range) which requires 2 drops to each 5 ml. standard.

[1] Clark and Lubs, 1917.

[2] Cohen, 1927; Hodgman and Holmes, 1941.

[3] Clark and Lubs, 1917; Hodgman and Holmes, 1941.

Variations within this range or a slightly smaller one, pH 6.3 to pH 8.5, are readily tolerated by most fresh-water fishes if these variations in pH result from the relatively small amounts of carbon dioxide and carbonates and sulfates of calcium and magnesium that are usually found in fresh waters.

However, Ellis and Jones (1945) have found that the susceptibility of trout to changes in temperature and dissolved oxygen is markedly increased by shifting the hydrogen-ion concentration from pH 8 to pH 6 with either hydrochloric or sulfuric acids. The actual amounts of acid used were small so that this change in sensitivity to temperature and reduced dissolved oxygen is not due to the specific toxicity of the acid. Several factors are involved but these findings are introduced here to point out that it is neither accurate to state that any given pH is or is not harmful to fish life, nor sound to dismiss the pH determination as of no consequence merely because it falls in the range of hydrogen-ion concentrations commonly accepted as harmless to fishes.

There are certain gross limits to the hydrogen-ion concentrations beyond which rapidly lethal effects are almost inevitable if fishes are exposed to such waters for even a short time; namely, acidity in excess of pH 4.0 and alkalinity greater than pH 9.5. Many acids and their acidic salts, however, kill at hydrogen-ion concentrations much less acidic than pH 4.0 and various alkalis and alkaline salts are lethal in waters less alkaline than pH 9.0 (Ellis, 1937).

In general, strong acids and alkalies kill by damaging the gills as well as by the systemic action of these compounds on the fish. Sulfuric, nitric, and tannic acids react with the mucus, coating the gill filaments so that oxygen absorption and branchial circulation are hampered and death may result before specific toxic systemic effects are observed (Ellis, 1937; Westfall, 1945). Acetic acid causes the filaments to swell which also interferes with oxygen absorption and the circulation of the gill filaments producing petechial, and later, general hemorrhages. Some acids as lactic acid and alkalis as ammonium hydroxide have pronounced systemic effects which are usually lethal before gross effects on the gill filaments are noted.

Considering the various possibilities, pH determinations lying outside the range pH 6.0 to pH 8.7 indicate that the usual balance of carbon dioxide and the carbonates and sulfates of calcium and magnesium has been disturbed either by the presence of too large a quantity of one or more of these compounds or by the addition of other substances to the physico-chemical complex of the water. Generally such deviations point to conditions at least unfavorable to fish life. It must be remembered in this connection that many animals including man can exist under conditions which are definitely harmful for varying periods of time, so that the presence of fishes in waters having hydrogen-ion concentrations outside this rather narrow range of pH does not prove that these waters are favorable for fish life. Supporting analyses of the water and surveys of the associated biota must be considered with the evidence offered by the presence of fishes.

The most conspicuous exceptions to waters having hydrogen-ion concentrations outside the limits given and supporting certain species of fishes will be found in waters of low conductivity from some mountain streams and various bogs and swamps. Small amounts of carbon dioxide can alter the hydrogen-ion concentration appreciably if the water is of low conductivity and poorly buffered. It is not surprising, therefore, that mountain streams carrying melted snow water are often slightly acidic and that bog and swamp waters which receive large contributions of carbon dioxide from disintegrating plant material frequently have hydrogen-ion concentrations betwen pH 6.0 and pH 4.5. However, if the total acidity of these waters of low conductivity is determined, it will be found to be very low.

It is evident, therefore, that the total acidity or the total alkalinity, the free carbon dioxide, the specific conductance, and the dissolved oxygen all be considered with the pH determinations in the final evaluation if the significance of the hydrogen-ion concentration is to be found. It must be repeated that hydrogen-ion concentration is the resultant of several factors and that pH values outside the expected range point definitely to disturbances of these factors, many of which are of large importance to fish.

In reporting hydrogen-ion concentration, the method by which it was obtained and the temperature at which the determination was made should always be stated.

ALKALINITY AND ACIDITY

Natural waters exhibit wide variations in relative acidity and alkalinity, not only in actual pH values, but also in the total amount of dissolved material producing the acidity or alkalinity. The concentration of these compounds and the ratio of one to another determine the actual pH and the efficiency of buffering in a given water. As the lethal effects of most acids begin to appear near pH 4.5, and of most alkalis near pH 9.6, it is evident that buffering in the stream water capable of preventing sudden shifts to these extremes on the addition of strongly acidic or alkaline effluents can be of paramount importance in the maintenance of life. Therefore, the determination of total acidity and total alkalinity of the water is necessary among other things to establish the capacity of a stream to neutralize many types of wastes (p. 48).

ALKALINITY

Alkalinity of waters, as usually interpreted, refers to the quantity and kinds of compounds present which collectively shift the pH to the alkaline side of neutrality. As the alkalinity of natural waters is generally the result of carbonates, although other compounds may be involved in polluted waters and waters from various mineralized areas, alkalinity is usually expressed in terms of carbonates and of calcium carbonate in particular. Hence, three kinds of alkalinity are usually designated; namely, hydroxide (OH), normal carbonate (CO_3), and bicarbonate (HCO_3), and the entire group summed as total alkalinity.

The determination of the particular alkalinities present and the quantity of each in any sample of water is made by titrating with a standard acid (0.02 N H_2SO_4) using two indicators, phenolphthalein and methyl orange. As the pink color of the phenolphthalein is due to the presence of hydroxide or carbonate, but not bicarbonate (for convenience referred to as phenolphthalein alkalinity), and as methyl orange is yellow in the presence of any of the three (hydroxide, carbonate, or bicarbonate), but is red in an acid medium at approximately pH 4.4, the desired alkalinities can be separated, and specific values calculated.

Various combinations of the different kinds of alkalinity occur. Carbonate (sometimes referred to as normal carbonate) and either hydroxide or bicarbonate may be present in the same sample, but hydroxide and bicarbonate are not found together due to the reaction between them. Hence, there are five conditions of alkalinity possible in the sample, namely, carbonate, bicarbonate or hydroxide alone or mixtures of carbonate and hydroxide, or carbonate and bicarbonate.

As the carbonates have a definite influence on the fauna of fresh waters and as these compounds exist in three forms, namely, free carbon dioxide, which in water forms the weak acid hydrogen carbonate or carbonic acid, bicarbonate and carbonate, it is advisable to consider each form separately.

CARBONATE AND BICARBONATE

Carbonates and bicarbonates in natural unpolluted waters supporting good fish faunae, range from 0 to 350 p. p. m. (expressed as calcium carbonate), with the usually expected values lying between 45 and 200 p. p. m. In these quantities the carbonates and bicarbonates have little direct effect on the fishes. There are, however, three indirect effects of these compounds that do influence the life of fishes materially.

First, the free carbon dioxide and the bicarbonates are necessary to the plant life of a stream, upon which the fauna depends for complete food chains, but, even though the variation in carbonate content is large in streams with excellent fauna, the small quantity of carbonates necessary for phytoplankton and other aquatic plants is practically always present. This is evident from the excellent fish fauna in many mountain streams and lakes, the waters of which have extremely low carbonate content. The buffering and neutralizing effects, that is, the chemical protection afforded by the carbonates against acids is often a major factor in determining the severity of acid pollution. The carbonates also serve as precipitants of many elements and compounds thereby tending to hold the heavy metals as iron, manganese, and zinc to non-toxic low levels, and precipitating out many harmful substances which enter the stream as pollutants. For example, copper sulfate in hard water is much less toxic to fishes than the same concentration of copper sulfate in soft water (Ellis, 1937), because the copper is largely precipitated out of the hard water as a carbonate. As the free carbon dioxide in water acts as a weak acid, it is discussed under acidity.

Hydroxides are rarely found in natural waters unless added through pollutants or waters from mineral springs and mineral fields. In some streams, however, receiving certain types of chemical wastes, great damage to the fauna may result from the hydroxide alkalinity. Although the hydroxide is important as a pollutant, it is of negligible value in most fresh waters.

ACIDITY

Acidity in natural unpolluted waters is usually due to the presence of carbon dioxide and several organic acids as tannic and humic. However, in polluted waters, both those receiving runoff from mineralized areas and those polluted by industrial effluents, almost any kind of acid or hydrolizable salt can be expected. The total acidity is of importance, not only because of the toxic effects of the various acids (discussed under hydrogen-ion concentration), but as a protection against strongly alkaline pollutants, and because the quantities of soluble salts of heavy metals are raised in acid waters which dissolve these elements out of rocks, silts, and muds.

The free carbon dioxide in most waters is seldom present in large quantities due to the reaction with other compounds in solution and to constant aeration. It has been observed that 90 percent of the waters containing good fish fauna have less than 2 ml. of free carbon dioxide per liter. If 3 ml. or more per liter are found, organic pollution is suspected, although some lakes, ponds, and bogs may approach, or even exceed, this figure under normal conditions.

In water-quality studies, the determination of free carbon dioxide is of importance because this gas is used more readily by the phytoplankton than either bicarbonates or carbonates, it may indicate organic pollution, and if present in sufficient amounts, it is specifically toxic to most aquatic organisms.

Mineral acids and many hydrolizable salts are often harmful in very small quantities due to the changes in pH which they may produce and to the specific toxicity of the individual compounds. Consequently, these substances must be considered individually although total acidity determinations will give valuable data concerning the amounts present.

METHODS

ALKALINITY

Titrate a 100-ml. sample in a 250-ml. Erlenmeyer flask, with 0.02 N sulfuric acid solution using phenophthalein (5 drops) as an indicator until the pink color just disappears and record the number of milliliters of acid used.

Add methyl orange indicator (5 drops) and continue the titration until the yellow color characteristic of the alkaline phase of this indicator turns to a definite orange, and record the number of milliliters of acid required. It is often advisable to carry a blank of distilled water and methyl orange for comparison, as the end-point of methyl orange is very difficult for many persons to detect, especially anyone who borders on color blindness. This group of persons can use to great advantage the indicator known as xylene cyanole-methyl orange which has a definite blue component disappearing at the end-point.

If, on the addition of the phenolphthalein to the sample, it remains clear and does not turn pink, immediately proceed with the methyl-orange titration.

ACIDITY

Free Carbon Dioxide

Fill a 100-ml. Nessler tube with the sample and using a glass rod with a foot almost as large as the tube, stir the solution gently to avoid loss of carbon dioxide, and titrate to a faint permanent pink color, using phenolphthalein, with N/44 sodium hydroxide solution.

The number of milliliters required for this titration multiplied by 10 gives the carbon dioxide content in parts per million. This value in parts per million of carbon dioxide can also be obtained somewhat more accurately from the pH and total alkalinity using Moore's (1939) nomographs. Parts per million of free carbon dioxide multiplied by 2.272 gives p. p. m. acidity as calcium carbonate.

Total Acidity .

Titrate a 100-ml. sample in an Erlenmeyer flask to a faint, permanent pink, using phenolphthalein, with 0.02 N NaOH solution. The amount of hydroxide used is equivalent to the same number of milliliters of 0.02 N sulfuric acid.

The acidity can be reported as acid or as the equivalent in calcium carbonate. To convert from milliliters of acid to parts per million of acidity expressed as calcium carbonate, multiply the milliliters of acid by 10.

In using this method for total acidity in the presence of aluminum and iron salts, (these salts do not enter into the reaction with any degree of speed at ordinary temperatures) the reaction may be quite slow and the first extremely faint persistent pink color should be taken as the end-point, especially if aluminum is present, as a partial resolution of aluminum hydroxide may occur.

If acidity resulting from free mineral acids is to be determined, use methyl orange indicator and titrate (with 0.02 N NaOH) until the pink color characteristic of the acid phase of methyl orange just disappears. If ferric and aluminum salts are present in appreciable quantities, this result for mineral acids will be too high. To correct for this error, determine the total acidity caused by mineral acids, the salts of iron, and aluminum by titrating at boiling temperature using phenolphthalein as an indicator. From this value subtract the acidity due to the presence of salts of iron and aluminum from calculations based on the previously determined amounts of these compounds. This gives a more accurate value for the acidity resulting from mineral acids. This procedure is especially necessary in the study of waters from coal mines, slag piles, and metal-pickling works.

If no acidity resulting from mineral acids is present, the total acidity is usually taken as a measure of free carbon dioxide. However, in pollution studies other weak acids or compounds which will neutralize sodium hydroxide may be present even though the pH is above the methyl-orange end point. In these situations, a spuriously high value for free carbon dioxide will be obtained. Caution, therefore, must be exercised in assessing a value for free carbon dioxide in any unknown water.

CALCULATIONS OF ALKALINITY

Several sets of relations between hydroxides, carbonates, and bicarbonates in solution exist and have been carefully worked out by the physical chemists (for details consult standard texts). However, five of these relations are of interest to the aquatic biologist in water-quality studies, to enable him to calculate the various units of alkalinity in a given water. These relations and the calculations based on them are set forth in the following paragraphs.

If there is phenolphthalein alkalinity present and no methyl-orange alkalinity, then the total alkalinity is due solely to hydroxide. This follows because bicarbonate and hydroxide cannot exist together in any appreciable amount due to the reaction between them. Were carbonate present, there would be a methyl-orange titration to satisfy the bicarbonate formed on titrating the carbonate with acid to the phenolphthalein end-point. The hydroxide alkalinity can be expressed in parts per million as calcium carbonate, by multiplying the number of milliliters of 0.02 N sulfuric acid used in the phenolphthalein titration by ten.

If the number of milliliters of standard acid used to discharge the pink color of phenolphthalein is equal to that necessary to attain the methyl-orange end-point after the phenolphthalein end-point has been reached, all of the alkalinity is normal carbonate. This is true because the amount of acid used in titrating the carbonate to the phenolphthalein end-point, which merely reduces the carbonate to the bicarbonate form is equal to that necessary to change the bicarbonate so produced over to carbonic acid in the methyl-orange titration. Therefore, the total number of milliliters of acid used for both phenolphthalein and methyl-orange titrations is multiplied by 10 to obtain the normal carbonate-alkalinity in parts per million of calcium carbonate.

If there is no phenolphthalein alkalinity but some methyl-orange alkalinity, only bicarbonate is present for normal carbonate and hydroxide do not exist in any appreciable quantities in a solution more acid than about pH 8.3, the approximate end-point for phenolphthalein in titrations of many natural waters.

If the phenolphthalein alkalinity is greater than one-half the total alkalinity, both hydroxide and carbonate are present. As bicarbonate, which cannot exist in appreciable quantities with hydroxide, is absent, this phenolphthalein titration represents the amount of acid necessary to neutralize the hydroxide plus that required to change the carbonate to bicarbonate. The methyl-orange titration, in this case, gives the amount of acid necessary to change the bicarbonate thus formed to carbonic acid. Therefore, the total number of milliliters of acid, minus the milliliters used in the phenolphthalein titration gives the number of milliliters of acid required for the methyl-orange titration, which represents the bicarbonate formed on titration of the carbonate to the phenolphthalein end-point. As the reduction of this bicarbonate to carbon dioxide requires the same number of milliliters of acid as were required to reduce the carbonate to bicarbonate, the normal carbonate can be calculated by multiplying the difference between the total alkalinity and the phenolphthalein titration by 2 and this product by 10 to give p. p. m. of calcium carbonate. Therefore, twice the phenolphthalein titration gives the number of milliliters of acid necessary to neutralize the hydroxide. This figure multiplied by 10 expresses the hydroxide alkalinity in p. p. m. calcium carbonate.

If the phenolphthalein titration is less than one-half the total, then carbonate is present plus some bicarbonate. As previously shown, the carbonate requires the same amount of acid to form bicarbonate as the bicarbonate needs to produce carbonic acid. Therefore, if the methyl-orange titration is greater than the phenolphthalein titration (as in this case where twice the phenolphthalein is less than the total) then the extra amount of acid needed in the methyl-orange titration was required by bicarbonate present in the sample. Therefore, normal carbonate as p. p. m. calcium carbonate is equal to twice the phenolphthalein titration in milliliters of acid times 10. Likewise, bicarbonate in p. p. m. of calcium carbonate is equal to the total alkalinity titration minus twice the phenolphthalein titration times 10.

If more accurate determinations are desired, other procedures are available. During recent years many investigators have criticized the method of determining free carbon dioxide and normal carbonate, bicarbonate, and hydroxide alkalinity in which phenolphthalein is used as an indicator. Also, certain assumptions currently used have been found to be inaccurate. The sodium-hydroxide titration method for estimating free carbon-dioxide content of water tends to give higher values than actually exist when only a few parts per million are present (De Martini, 1938). For waters high in carbon dioxide, the reverse is true. As the phenolphthalein end point varies with different concentrations of alkali, the assumed pH at the end-point does not always agree with the hydroxyl-ion concentration as computed from the hydrogen-ion concentration determined by thymol blue or by glass electrode pH meter (De Martini, 1938). Besides, the assumptions used in the phenolphthalein-methyl orange titrations that neither carbon dioxide and normal carbonate, nor bicarbonate and hydroxide can exist together are not strictly quantitative (Moore, 1939).

Consequently, Moore (1939) using the formulae of De Martini (1938) devised a method in which it is possible to calculate from the hydrogen-ion concentration and total alkalinity of a water the amounts of carbon dioxide, bicarbonate, normal carbonate, and hydroxide present. Graphs were made based on the formulae as influenced by temperature and the concentration of dissolved salts. By reading the pH with a glass electrode, making a total alkalinity titration potentiometrically, and then reading the nomograph, more accurate results can be obtained.

REAGENTS FOR ALKALINITY AND ACIDITY DETERMINATIONS

Phenolphthalein indicator. — A 0.05 percent solution in 50 percent alcohol.

Methyl-orange indicator. — A 0.05 percent aqueous solution.

Xylene cyanole-methyl orange indicator. — A solution containing 0.02 percent methyl orange and 0.1 percent xylene-cyanole in distilled water.

Standard 0.02 N sulfuric acid. — Measure out the proper amount (49.04 grams per liter of concentrated sulfuric acid, specific gravity circa 1.84) for a 1 N stock solution. To make the 0.02 N solution, take 20 ml. of the stock 1 N standard and dilute to one liter. Check this standard with a glass electrode pH meter or a standard alkali solution to establish its true normality. This pH reading from the glass electrode can be used to calculate the normality either from tables or the formula $\log \frac{1}{H^+} = \text{pH}$ where H^+ represents the hydrogen-ion concentration expressed in mols.

Stock sodium hydroxide solution. — Prepare a stock solution of NaOH by first washing off the chalky outside coating of carbonate on the sticks or beads of NaOH in a beaker of distilled water. Pour off the solution and dissolve the remaining NaOH in glass distilled water (approximately 20 grams per liter). Standardize this stock solution (which is approximately 0.5 N) against a standard sulfuric acid solution using methyl orange as the indicator.

Solution of sodium hydroxide (N/44). — To prepare the N/44 solution from stock, use the well known formula $\frac{\text{normality of desired solution times 1,000}}{\text{normality of stock solution}}$ equals the number of milliliters of stock solution to be diluted to one liter to make the proper standard.

Standard 0.02 N sodium hydroxide. — Prepare from stock solution using formula given above.

SUSPENDED MATTER

Natural waters, particularly if they are moving rapidly or are subject to strong wind, wave, or current action, carry varying quantities of suspended matter. This material is often of importance to the aquatic biologist as bottom conditions, light penetration, bacterial content, and various other features of the aquatic complex can be modified seriously by suspended matter. The inanimate suspended matter may be present in one or more of three forms, namely, material heavier than water, that is, substances which because of their particle size and specific gravity sink or "settle out" rather rapidly if the water is undisturbed; substances which because of the small size of the particles, even though the specific gravity may be greater than that of the water, remain suspended and will not settle out for many hours, if at all; and substances which are lighter than water and consequently tend to rise through the water forming layers, mats, or scums at or near the surface. Many natural waters also support varying numbers of living bacteria and plankton organisms, which may be distributed throughout the water or which may be concentrated in bands or layers at different levels. If these organisms are present in sufficient quantity, that is 0.1 percent or more by volume, they are treated separately in studies of suspended matter. However, in most flowing streams, bacteria and plankton constitute only a small portion by volume of the total suspended matter.

Many effluents as mine slimes, sewage, and cannery wastes often contain large volumes of suspended substances. It is, therefore, frequently necessary for the aquatic biologist to measure the amounts of substances in suspension in both normal and polluted waters. A sequence for the determination of suspended matter follows:

COARSE MATERIAL

The samples should be collected directly through a screen having meshes 1/16 to 1/10-inch square, or if the sample is taken from a sampler, it should be poured through such a screen before beginning the other quantitative determinations. This screening will remove the larger particles as pieces of sticks and leaves, fine gravel and bits of raw sewage. If only a small quantity of coarse material is retained on the screen, it may be disregarded, but if the screen catches coarse suspended matter aggregating 2.50 percent or more by volume, this material must be measured. Usually the larger the particles, the less uniform the distribution throughout the mass of water so that in the determination of the coarse material, the error will be fairly large; that is, the accuracy of the determination does not justify the use of small fractions when reporting the results.

Coarse suspended matter is measured in percentage by volume. Take as large a measured volume of the sample water as is convenient (minimum, however, of 2 liters) and pour it carefully through the screen. The material retained by the screen is then transferred in the wet state to a graduated cylinder, large pieces of leaves and other obviously accidental components being rejected when the transfer is made. The volume of this material, disregarding any water which may separate out, can be read in milliliters from the cylinder and the percent volume computed. While collecting the coarse material, the sample must flow through the screen freely, as any clogging of the screen mesh will cause retention of finer material which should pass through to be measured otherwise.

RAPIDLY SETTLING PARTICLES AND DIRECT SEDIMENTATION

The definition of this group of suspended substances involves a time factor which is designated here somewhat arbitrarily as one hour, for actually the materials classified as rapidly settling particles grade in a continuous series into those classified for convenience as the slowly settling particles. However, it has been observed in the field that suspended matter which does not settle out in one hour is very finely divided and may not settle out for many hours. Besides readings can be made at any time during the hour without vitiating the end result.

Both the rapidly and slowly settling particles are introduced into natural waters largely by wind, wave, and run-off erosion, landslides, and glaciers, and into polluted waters through effluents from stamp mills, rock sawmills, gravel, and coal washers and various types of industrial plants.

To the aquatic biologist, suspended matter of this type is important in that it may rapidly and seriously impair bottom conditions so that nesting sites will be destroyed and the bottom faunae, which have very significant positions in the food chains on which fishes and other aquatic animals depend directly or indirectly for a considerable portion of their food, will be smothered out. The detrimental action of deposits of solids, introduced by man through industrial activities or following agricultural and deforestation changes in the surface of the land, onto the floors of natural streams and lakes has been a growing hazard to fish life for many years.

With the advent of extended programs for improving large portions of our inland waters for power, flood control and other purposes, these substances which settle out readily in the quieter portions of a normal stream are now being deposited in prodigious quantities in the slack waters of impoundments. The sedimentation rate, that is, the rate at which these substances leave the water follows Stokes' law and depends upon the density of the fluid through which the particle is falling (in this case, water), the density or relative weight of the particle, that is, the specific gravity of the particle, and the size of the particle. As these particles are usually very irregular in shape, the diameter of a sphere which would fall at the same rate as the particle (Stokes' diameter) is chosen as the measurement for the relative particle size.

In water quality studies, it is often essential to measure quickly not only the amount of suspended matter in the water but also to learn how rapidly any or all of this material would be deposited on the bottom were the stream slowed. The effects of the suspended matter while still in the state of suspension on light transmission and other water conditions are also often significant. As several procedures are involved, a total sedimentation time of one hour has been found by actual field experience to be both convenient and ample for most field work. However, as is discussed under the procedure, it may be desirable to lengthen the total sedimentation time in some particular cases. As the sedimentation time according to Stokes' law varies with the density of the fluid and as the density of water varies with temperature, the temperature of the water at the time the observations are made must be recorded or, for more uniform results, all samples should be studied at approximately 25° C.

The standard 100 ml. pyrex water and sedimentation tubes as approved by the American Society for Testing Materials in the examination of oil, water, and sediment mixtures by the petroleum industry, have been used by the authors in the measurement of suspended material which will settle out rather rapidly.

Six of these tubes (each provided with a rubber stopper which has been boiled previously with sodium carbonate and thoroughly cleansed with distilled water) are mounted in a rack resembling standard wooden test-tube racks. When not in use, the sedimentation tubes are wrapped in cloth and packed in this rack so that the breakage in the field will be minimal.

Three sedimentation tubes should be filled exactly to the 100 ml. mark through the screen directly from the stream if possible. If it is not feasible to fill the sedimentation tube directly, the sample from which the sedimentation tube is filled must be as fresh as possible and must have been shaken continuously to prevent the settling out of material. It is often difficult to obtain a true sample as many types of suspended matter begin to settle out as soon as the sample is removed from the stream and others tend to aggregate or agglutinate if the sample is held for even a few hours after removal from the stream. The sedimentation tube, after it has been filled, is stoppered tightly and placed in the upright position in the rack, care being taken that the rack is level and that the tube stands vertical.

By means of the graduated scale on the sedimentation tube, the amount of suspended matter which has left the water is read directly as percent by volume at the end of 5 minutes, 10 minutes, 15 minutes, 30 minutes, and one hour. These time intervals have been adopted as the result of extensive field tests, but it is obvious that other time intervals might be required for specific problems. However, several readings should be taken as a sedimentation curve showing the amount and rate of sedimentation is always helpful in the interpretation of results. Such a curve can be constructed from the data obtained from the sedimentation tube readings.

As the sedimentation proceeds, the sorting of the various components in the mixture of suspended matter becomes apparent because, according to Stokes' law, there will be a sorting depending upon the size and density of the various particles in the mixture of suspended material. It must be remembered in this connection that the suspended material carried by natural waters, even though these waters be unpolluted, is very rarely composed of only one type of material. Consequently, the determination of particle size cannot be made by the ordinary sedimentometer. Very often layers of different colors appear showing that the original load of suspended matter was composed of several kinds of material which were not visibly evident in the mixture as a whole.

Starting at the bottom of the sedimentation tube, these layers are designated successively as the alpha, beta, gamma, etc., layers, according to the number present. The percentage by volume of each layer can be read directly from the tube graduation. In general, the alpha layer will be made up of the heaviest and largest particles and the layers nearer the top of the lighter and smaller particles. As it sometimes happens, some one or more of these layers contains fluorescent material when exposed to ultra violet light (p. 92). These layers are often valuable in tracing the source of certain suspended material, and in following the spread of various types of pollution, for example, mine slimes, downstream.

If, as is the case in some investigations, a longer sedimentation time is desired, the readings can be continued at intervals until complete sedimentation has been obtained. The limiting factor is, of course, time and it is rarely practicable to continue the sedimentation readings more than 2 or 3 hours in the field.

SLOWLY SETTLING PARTICLES AND TURBIDITY MEASUREMENTS

This type of suspended matter can be measured readily in two ways, either by continuing the readings on the undisturbed sedimentation tube until all of the suspended particles settle out, or by determining the turbidity photoelectrically. As the first procedure may require hours or even days, turbidity readings are much more practical, in most cases, after the rapidly settling particles have been removed.

Although several methods have been proposed for the determination of turbidity, the photoelectric measurement of turbidity seems the most satisfactory considering all conditions to be met in water-quality studies. For this work, any one of the several makes of photoelectric colorimeters can be used. Compactness and sturdiness are, of course, desirable characteristics for field use. In our field equipment, the photelometer is carried in a special box heavily lined with sponge rubber and the illumination obtained by attaching the instrument to the battery of the laboratory truck. In this way, a usable source of direct current of the proper strength is always available. Photometers are generally rated as rather delicate instruments, but in our field operations we have carried them thousands of miles and have worked under many conditions of weather, storm, and heat, with no breakage or loss of efficiency.

The photoelectric method of turbidity determination is based on the measurement of the light striking a photoelectric cell after passing through a known thickness of the test water in a standard polished-glass cell as compared with the transmission of light from the same source and of the same initial intensity as transmitted through a similar quantity and thickness of distilled water. The instrument is connected with the battery and the light adjusted so that the galvanometer reading for distilled water is exactly 100. The carriage is then shifted. A similar quantity of the sample water in a matched glass cell is then subjected to the same light and the transmission of light through this sample measured by the photo-electric cell and galvanometer.

Three turbidity readings are recommended routinely on waters where heavy loads of suspended matter are obvious, but the observer must make as many determinations as the particular problem requires.

TOTAL TURBIDITY

This should be read at once from a sample collected through the screen before any settling out has taken place. If the proportion of rapidly settling particles is large, it may be difficult to obtain an accurate determination immediately after the sample is taken. However, total turbidity is easily measured for most waters. The outstanding exceptions are rapidly moving streams carrying heavy loads of mine slimes or erosion run-off.

FIVE MINUTE TURBIDITY

When the samples were taken for rapidly settling particles and direct sedimentation, 3 tubes were filled and placed in the rack. At the end of the first 5 minutes, take one of these tubes and draw a sample from the middle of the tube with a dry 10 ml. pipette. Transfer this sample at once to the photelometer cell and read. This will give the average 5 minute turbidity. Although there will be some stratification in the supernatant fluid in the sedimentation tube at the end of 5 minutes, it is usually not marked and the mid-tube sample will give an average value. The coarser rapidly settling particles will have left the fluid so that this turbidity reading is not difficult to make, for in general after the sample has been undisturbed for 5 minutes, the water is essentially free from those particles which are held in suspension only by rapid current flow.

RESIDUAL TURBIDITY AFTER ONE HOUR

The quantity of slowly settling particles present in the sample is measured by this determination, for in general the particles held in suspension by the movement of the water will have settled out at the end of one hour.

Take one of the two remaining tubes of the sample under consideration and carefully draw a 10 ml. sample with a dry pipette from the middle of the tube, that is, at a point approximately halfway between the surface of the water and the top of the material which has been deposited in the bottom of the tube. Transfer to the photelometer cell and mix thoroughly. Read at once. As there is usually a definite stratification of the supernatant fluid at the end of one hour, the reading is referred to as average residual turbidity.

If the water is colored either by natural components, such as the extracts from leaves and vegetation commonly found in bog and swamp waters or by dyes and other highly colored substances frequently present in trade wastes, correction for the color of the water must be made. As both pigments in solution and solids in suspension will reduce the amount of light transmitted, the readings for turbidity will be too high in colored waters, unless this correction is made.

Filtration through one or more layers of high grade chemical filter paper capable of retaining very finely divided material is usually sufficient to remove the suspended matter from most waters. The filtrate, of course, must be clear. However, some silts will pass through filter paper and some dyes and other pigments will be adsorbed on filter paper. Samples which cannot be filtered should be centrifuged. For this purpose a hand centrifuge is carried in the field. Having obtained a sample of water free from the suspended matter, determine the amount of light screened out by this sample in terms of the distilled water standard and deduct this from the value obtained when both color and suspended matter were present. The resultant will, of course, be that of the turbidity produced by the suspended matter.

TURBIDITY OF VERTICAL SECTIONS OF LAKES AND IMPOUNDMENTS

When it is desirable to obtain continuous readings of turbidity at any given depth or to measure turbidity at very short intervals in a vertical section of a lake or impoundment where density currents, thermal stratification or other causes produce bands of water having different turbidities, a submersible photoelectric unit has been used by the authors (Ellis, 1940). This consists essentially of a photoelectric cell in a water-tight housing fixed in a carriage opposite an electric light bulb. The space between the photoelectric unit and the light can be adjusted to meet the expected degree of turbidity as previously determined from the Foerst samples. Wires supplying current to the light and connecting the photoelectric unit with a galvanometer are bound in a cable attached to the steel rope carrying the apparatus. The readings can be made continuously at any depth from the galvanometer on the deck of the boat.

TURBIDITY AND LIGHT OF SPECIFIC WAVE LENGTHS

In addition to measuring the total turbidity because of suspended material, it is often essential to determine the screening power of the existent turbidity, either natural or artificial, for light of particular wave lengths. Using screens of colored Corning glass, for which the transmission curves are known, between the source of light and the glass cell of the photelometer, transmission curves covering any range in the visible light series can be obtained readily for the sample used. This procedure is sufficiently accurate for most field water-quality studies. However, for exact determinations any of the standard spectrophotometers can be used. These instruments make possible the use of very narrow bands of relatively monochromatic light and the transmission curves obtained are often very helpful in specific turbidity examinations. In the case of clear or colored solutions containing various specific pollutants in solution, the spectrophotometer (p. 93) is also useful in that the transmission curves of many of these substances are characteristic and can be used in determining the spread of a pollutant downstream from the source of pollution. The spectrophotometer is, of course, a laboratory instrument and samples must be returned to the base laboratory for such studies.

PARTICLE SIZE

The measurement of particle size by determining the Stokes' diameter is not feasible for mixed samples in the field. However, the range of particle size can be determined with sufficient accuracy for most field studies by placing a few drops of the water on a microscope slide and under a moderate power objective measuring the particles with an occular micrometer. As the particles are usually very irregular, the maximal and minimal sizes as well as the average should be recorded and measurements made covering two axes.

TURBIDITY STANDARDS AND DATA

The readings obtained in these measurements of turbidity and light transmission can be used in several ways. For most purposes the percentage of light screened out by the suspension or colored water is a suitable expression of results. This value is obtained by subtracting the photelometer readings from 100 and denominating the resultant percentage as the distilled water standard is always set at 100.

Various turbidity units have been proposed and the one defined by the American Public Health Association (1938) is used quite widely. Standardized suspensions of Fullers' earth of known turbidity as measured in A.P.H.A. units can be prepared. Using these suspensions, the photelometer and its cells can be standardized, and a curve drawn from which readings can be made. As the standard suspensions are difficult to prepare, it is recommended that these be purchased through the chemical supply houses.

In the interpretation of turbidity data, the light penetration through known depths of water of known turbidity is often helpful. Using the formula

$$y = \frac{\log\ (1 - x)}{\log\ (1 - p)}$$

in which x equals total percentage of light screened out, p the percentage of light screened out by sample, and y the depth desired divided by the thickness of the cell through which the light transmission was measured, by substituting any desired value for either x or y the penetration depth relations can be computed (Ellis, 1934). These values are often useful in studies of deep lakes and impoundments.

It is not possible to set standards for minimal turbidity or loads of suspended matter tolerated by fishes as there are many factors to be considered in evaluating the detrimental action of suspended matter and the more serious hazards develop slowly and often insidiously. However, some actual findings made by the authors in field pollution studies may be helpful. Water from the snout of Nisqually Glacier on Mt. Rainier, from which glacier a very muddy stream flows, carried from 0.1 to 0.2 percent of suspended matter by volume which settled out in 1 hour, and had a residual turbidity of 150-170 A.P.H.A. units. Similar values were found for other glacier waters, and these streams, turbid as they were, supported good trout fauna at points where the suspended matter which would settle out in 1 hour was 0.15 percent by volume and the residual turbidity was 110 A.P.H.A. units.

In contrast, Whitewood Creek in South Dakota Black Hills, heavily polluted with mine slimes and rock powder at points where the fish fauna had been driven out completely, carried over 22 percent by volume of solids which would settle out in 1 hour and had a residual turbidity of over 48,400 A.P.H.A. units. Fishes reappeared only when the suspended matter settling out in 1 hour had dropped to approximately 3 percent by volume and the residual turbidity to 720 A.P.H.A. units. Apparently both groups of suspended particles are concerned, as less than two miles upstream from the point where the fish first reappeared, the suspended matter settling out in 1 hour was approximately 3 percent by volume but the residual turbidity had risen to 20,200 A.P.H.A. units. These values are not given as defining limits but to point out to the observer some of the variations to be expected and to emphasize the fact that other conditions must be considered along with the suspended matter in making a true evaluation of the suspended matter.

SETTLEABLE SOLIDS

In the preceding sections attention has been given to the suspended matter which passes readily through a screen of 1/10-inch mesh or smaller. These procedures are satisfactory for suspensions of muds, rock powders, many chemical sludges and inorganic wastes in general, but if sewage sludges, wood fiber, sawdust, or other wastes containing organic suspended matter are present in quantities not readily removed by the screen, the settleable solids are determined collectively, and then such fractionations as are feasible made.

Imhoff Cone

This glass cone which has a capacity of slightly more than one liter is mounted in the vertical position in a rack and filled exactly to the 1 liter mark with the unscreened water or effluent, that is, with the sample as collected directly from the stream or flume. The cone is covered with a plate of glass and is not disturbed for 45 minutes (short determination) or 1 hour and 45 minutes (standard determination). The cone is then twirled sufficiently to release any sediment which may have settled out on the sides of the cone, and returned to the rack, allowed an additional 15 minutes for settling and the volume of the deposit read from the graduations on the side of the cone. The reading will have been made, therefore, after 1 or 2 hours.

Graduated Cylinder

If the water or effluent contains considerable amounts of wood fiber or coarse organic matter, a 1 liter graduated cylinder is often preferable to the Imhoff cone. Proceed as directed for Imhoff cone.

LIGHT SUSPENDED MATTER

Numerous industrial wastes, many samples of sewage, and often run-off waters contain suspended matter, usually organic, which will rise through the water on standing. The volume of this fraction of the suspended matter is easily determined by separation.

Place a measured quantity, 250 ml. or more, of the water or effluent in a large glass-stoppered separatory funnel. At the end of 1 or 2 hours (note time exactly) draw off the fluid from below the layer or layers of material, which has risen to the top, into a graduated cylinder and measure. The volume of the suspended matter left in the separatory funnel is obtained by difference.

WATER HARDNESS

Water containing salts of calcium and magnesium, and to a lesser extent of iron and aluminum, and which requires a relatively large amount of soap to produce a lather, or if heated, forms a deposit on the container is referred to as hard water. Although the degree of hardness may depend on the quantity and type of salts present, for uniformity, hardness usually is expressed in terms of calcium carbonate, although reference is made frequently to hardness due to other specific compounds. For example, when the amount of hardness is equal to or less than the total carbonate and bicarbonate alkalinity (q.v.), it is designated as carbonate hardness, but if the hardness exceeds that alkalinity, the excess is called non-carbonate hardness and may be defined further as iron hardness, sulfate hardness, or some other hardness depending upon the salts present.

As the salts responsible for the carbonate hardness of natural waters usually are much in excess of those salts producing non-carbonate hardness, and as these same carbonates are chiefly responsible for the total alkalinity of the water, hardness and alkalinity are obviously very closely related and must be considered together for proper interpretation of the hydrobiological data. Although occasionally there may be sufficient non-carbonate hardness to render water unsuitable for certain fishes and other aquatic organisms, as sulfate hardness in the "gyp" and "alkali" waters from some of the plains and desert areas of the west, or iron and other metals from industrial effluents and mines, usually the non-carbonate hardness is of little importance to the fauna of a stream. Hardness determinations are consequently, for the most part, corroboratory to the findings on alkalinity. However, hardness is often a significant water characteristic in industrial operations and not infrequently hardness data are available which will be helpful to the biologist in evaluating conditions previous to his own findings.

METHODS

Total hardness may be determined readily in three different ways, namely, by the soap method, by the soda method, and by specific analyses for calcium and magnesium and any other metals present in significant amounts. These procedures make use of long-established chemical routines.

SOAP METHOD

This determination measures the soap-consuming power of the water, and since hardness usually depends primarily on calcium and magnesium salts, this method gives approximate determinations of the calcium and magnesium in a sample.

Measure a 50 ml. sample into a 250 ml. glass-stoppered bottle. Add the standard soap solution in small amounts (about 0.2 ml.), and shake vigorously after each addition of soap. When lather is first seen, lay the bottle on its side and wait until the lather either disappears or persists for 5 minutes, which is the true end point. If care is exercised with samples containing magnesium and calcium, a transient lather will be produced marking the removal of the hardness resulting from magnesium salts; and the amount of soap used should be noted at that time. The addition of more soap will cause this lather to disappear, but more lather will subsequently appear after further additions of soap and a lather which persists for at least 5 minutes will be obtained. The difference between the magnesium or false end point and the calcium or true end point represents the hardness due to the presence of calcium salts.

At best, this is only an approximate method, and the separation of the calcium from the magnesium hardness is still less exact. This method may be used with more quantitative accuracy in repeated routine analyses on a particular stream over a period of time, providing detailed analyses have been made for the chief metallic salts as a check on the soap method. Although the soap test has been described as a quick method, as the last three or four additions of soap solution should be very small (1 or 2 drops), and as after each addition of soap nearly 5 minutes will be required to follow the course of the lather, often a total of many minutes will elapse during a single determination.

The results, expressed as parts per million of calcium carbonate, are calculated by deducting the lather factor (p. 62) from the milliliters of soap solution used and multiplying that remainder by 20. If the water is more acidic than pH 4.4, it should be neutralized with sodium carbonate (0.02 N) to the methyl orange end point before starting the soap test. As samples colder than 10° C. give low results with this method, they should be warmed at least to that temperature before analysis. If the hardness is so great as to require 15 ml. or more of the soap solution, an aliquot part of untreated sample should be diluted to 50 ml. with carbon dioxide-free distilled water and the test repeated with the soap.

SODA METHOD

Non-Carbonate Hardness

Although this procedure is not as accurate as a gravimetric method, it gives fairly accurate data for this type of hardness.

Place 200 ml. of the sample and 200 ml. of distilled water each in 500 ml. pyrex flasks and bring each flask to the boiling point to drive off the carbon dioxide. Add 25 ml. of soda reagent to each flask while it is still hot and continue to boil for 10 minutes. Cool and rinse the contents of each flask into a 200 ml. measuring flask and make up to 200 ml. with carbon dioxide free water (some water was lost during boiling). Filter, and after rejecting the first 50 ml., which may be contaminated by the filter paper, titrate 50 ml. with 0.02 N sulfuric acid using methyl orange as an indicator. As the soda reagent is approximately 0.1 N and the sulfuric acid 0.02 N, multiply the difference between the milliliters of acid required to neutralize the soda reagent in distilled water and that in the sample by 20 to obtain hardness in parts per million as calcium carbonate. If more than half of the soda reagent has been used, take a smaller amount of the sample, dilute it to 200 ml. and proceed as above. Otherwise, low values will be found.

TOTAL HARDNESS

Neutralize the sample with sulfuric acid, as in the procedure for methyl orange alkalinity, and then follow the non-carbonate soda method. The carbonate hardness can be obtained by subtracting the non-carbonate from the total hardness.

DIRECT ANALYSES

If more accurate results are desired, analyze for calcium and magnesium (q.v.) and multiply the calcium value (parts per million) by 2.495 and the magnesium value by 4.115 to arrive at the respective hardness values due to the presence of salts of those two ions in the sample. If significant amounts of other metals are present, they too must be taken into consideration.

REAGENTS FOR HARDNESS

Stock soap solution.—Shake 100 grams of pure castile soap, powdered or in shavings, into one liter of 80 percent ethyl alcohol. Cover and put aside for one to three days, then, decant.

Standard soap solution. — Dilute a portion of the stock soap solution (approximately 9 or 10 times) with 80 percent ethyl alcohol until one ml. is equivalent to one ml. of the standard calcium chloride solution. Due allowance must be made for the lather factor (amount of standard soap solution necessary to produce a permanent lather in a 50 ml. sample of distilled water) so that 1 ml. of this soap solution (after subtracting the lather factor) exactly satisfies the hardness of 1 ml. of standard calcium chloride solution which in turn is equivalent to 1 mg. of calcium carbonate.

Standard calcium chloride solution. — Dissolve 0.5 gram of pure anhydrous calcium carbonate in a few ml. of dilute hydrochloric acid (avoid any loss by spattering). Add about 200 ml. of carbon dioxide-free distilled water. Neutralize with ammonium hydroxide until just alkaline, as indicated by litmus, and then add sufficient distilled water to make 500 ml. Store the solution in glass. One ml. of this solution is equivalent to 1 mg. of calcium carbonate.

Methyl orange indicator. — Use a 0.05 percent aqueous solution. Keep in a brown bottle or in the dark.

Standard 0.02 N sodium carbonate.—Weigh exactly 1.059 grams of pure dry anhydrous sodium carbonate of reagent quality and add sufficient boiled and cooled glass-distilled water to make one liter of solution.

Soda reagent, approximately 0.1 N.—Add sufficient distilled water to 2.0 grams of sodium hydroxide and 2.65 grams of anhydrous sodium carbonate, to make one liter of solution when cooled to 20° C.

Standard 0.02 N sulfuric acid.—Make up as described under alkalinity and acidity, q.v.

CALCIUM AND MAGNESIUM

CALCIUM

The importance of calcium compounds in the adjustment of the chemical complexes of fresh-waters has been pointed out in the sections on hydrogen-ion concentration and total acidity. Calcium also plays an important role, particularly in lakes and the lateral areas of impoundments, increasing biological productivity. Ohle (1934) found the biota of the lakes in north Germany to be poor if the calcium were less than 10 p.p.m., good when the calcium ranged between 10 and 25 p.p.m., and very good to rich if the calcium exceeded 25 p.p.m. Similar observations have been made in North America by Juday, Birge, and Meloche (1938).

OXALATE METHOD

This method is based on the principle of precipitating the calcium as oxalate, dissolving the precipitate in a solution of sulfuric acid, followed by a hot titration with potassium permanganate (Hale, 1907; McCrudden, 1911).

Procedure

1. Add a few drops of concentrated hydrochloric acid to a 250 ml. water sample and evaporate to dryness over a water bath.
2. After moistening the residue with concentrated hydrochloric acid to change the iron and aluminum oxides to soluble chlorides, add 30 ml. of distilled water (or more if necessary) to dissolve the calcium sulfate and heat to boiling. Filter and wash the residue on the paper with the rinsings, adding this liquid to the filtrate.
3. A few drops of bromine water are then added to the filtrate which is boiled gently for 5 minutes, to oxidize the iron to the ferric state.
4. Add 10 ml. of a 10 percent solution of ammonium chloride, to prevent the formation of insoluble magnesium hydroxide, make alkaline to litmus with concentrated ammonium hydrox-

ide, and boil gently for 5 minutes. Filter and rinse the precipitate from the beaker onto the paper and wash it with small portions of distilled water, adding these washings to the filtrate. The above steps have been followed to free the sample of iron and aluminum compounds. If the filtrate from a determination of iron and aluminum is available for use, the above steps may be omitted.

5. Warm the filtrate and while stirring, add slowly 10 ml. of saturated ammonium oxalate. After the mixture has been allowed to stand for 30 minutes in a warm place, filter out the precipitated calcium oxalate, and rinse it well with hot distilled water (save this filtrate for the determination of magnesium).

6. Transfer the filter paper and its contents into a beaker and add 30 ml. of 2 percent sulfuric acid. Heat to boiling and titrate with standard potassium permanganate until a pink color, permanent for one minute, is obtained. The number of cubic centimeters of 0.125 N permanganate used multiplied by 10 gives the calcium (Ca) in parts per million.

Reagents for Calcium Determination by Oxalate Method

Hydrochloric acid.—Concentrated.

Bromine water.—Add 10 ml. of liquid bromine to a liter-bottle almost full of distilled water (under the hood or out of doors). Caution! The fumes and solution are dangerous!

Ammonium chloride.—A 10 percent solution.

Ammonium hydroxide.—Concentrated.

Saturated ammonium oxalate. — Into about one liter of distilled water, place approximately 50 grams of ammonium oxalate. Use the supernatant fluid.

Sulfuric acid.—Two percent by volume.

Sulfuric acid solution (1:3).—Add slowly 250 ml. of concentrated sulfuric acid, stirring constantly, to 750 ml. of distilled water in a pyrex flask.

Standard potassium permanganate stock solution (0.2 N).—Dissolve 6.4 grams of potassium permanganate in distilled water and make up to one liter. Standardize this solution by titrating (at 90° C.) 25 ml. of standard ammonium oxalate (0.2 N, 14.210 grams per liter) diluted to 100 ml. and made acid with 10 ml. of 1:3 sulfuric acid. The end point is the first pink color permanent for one minute.

Working solution (0.125 N).—Make up as needed from stock solution (Use formula on p. 51). This standard solution should be checked frequently against an oxalate solution.

PICROLONIC ACID METHOD

As certain errors are known to occur in the oxalate method due to incomplete separations in the various filtrations and precipitations, for more accurate determinations of calcium, the picrolonic acid method is recommended. There are several sequences for this method which are satisfactory but as they are complicated laboratory procedures, the details are not given here. If the reader wishes to use the picrolonic acid method, he is referred to Cohn and Kolthoff (1943).

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MAGNESIUM

PHOSPHATE METHOD

This determination is based on the gravimetric method of McCrudden (1909) in which the magnesium is precipitated as magnesium ammonium phosphate.

1. Precipitate the iron, aluminum, and calcium compounds described under the oxalate method for calcium and to the filtrate thus prepared, add about one-ninth its volume of concentrated ammonium hydroxide. Follow this immediately with 10 ml. of a 10 percent solution of disodium phosphate, stir vigorously, and allow to stand at least 4 hours for the formation of the precipitate of the magnesium ammonium phosphate.
2. Filter the precipitate onto a quantitative filter paper being sure all the precipitate is retained. Wash the precipitate well with 3 percent ammonia water. Transfer the folded filter paper to a crucible which has been ignited, cooled and weighed.
3. Ignite the filter paper and its contents until almost white, cool in a dessicator and weigh.
4. Multiply the difference in weights by 873.6, the result being magnesium (Mg) in parts per million. This factor, 873.6, is derived from calculations involving the equivalent weight of the magnesium pyrophosphate ($Mg_2P_20_7$, resulting from ignition) compared to that of magnesium.

Reagents for Magnesium

(a). Di-sodium phosphate solution (10 percent). (b). Ammonia water (3 percent).

HYDROXYQUINOLINE METHODS

As magnesium is not a critical element in most water-quality evaluations, the phosphate method with all its limitations is usually accurate enough. However, in some specific cases a more accurate method is desired, and the use of hydroxyquinoline in either colorimetric or titration determinations of magnesium provides a procedure which eliminates the inaccuracy of the phosphate method due to incomplete precipitation. The hydroxyquinoline methods are, however, somewhat involved and the details are not given here. The reader is referred to Hoffman (1937) and Buydens (1942) should this more exact method be required.

NITROGEN DETERMINATIONS

AMMONIA NITROGEN

Ammonia and its salts are of interest in water-quality studies because ammonium compounds are generally detrimental or lethal if more than 2.5 p.p.m. of ammonia are represented, because more than 1 p.p.m. of ammonia in natural waters usually points to organic pollution, and because many of the lower plants and bacteria that are involved in the food chains upon which fishes depend can utilize ammonia as a source of nitrogen. However, the role of ammonia in the biological productivity of freshwaters is not too well defined. The usual sources of ammonia in natural waters are disintegrating plant or animal material, sewage or other organic wastes, and a few chemical processes as waste waters from rayon fibre mills.

The toxicity of ammonium compounds depends chiefly upon the amount of ammonia available but also upon the alkalinity of the water carrying the ammonium salt (Ellis and Chipman, 1936). Although detrimental effects may be expected if 2.5 p.p.m. or more ammonia are present in the water, many fishes, particularly carp, buffalo, and some sunfishes can tolerate from 3 to 10 p.p.m. of ammonia. As is the case with many other substances, the exact limit of toxicity of ammonia varies with many factors in the aquatic complex and these values must be taken as somewhat generalized.

METHODS

Ammonia is usually determined by some modification of the original method of Nessler (1856). The orange-amber color developed quantitatively by ammonia in a strongly alkaline solution of mercuric and potassium iodides, is matched against real or artificial standards, or the nesslerized ammonia is read photelometrically. If the amount of ammonia is between 0.1 and 1.0 p.p.m., the undiluted sample can be used for direct nesslerization after the removal of any interfering substances. Samples containing more than 1 p.p.m. of ammonia should be diluted with ammonia-free distilled water to the 0.1-1.0 p.p.m. range in which the reactions of the reagent are optimal. If ammonia is present in very small quantities or if there are unusual interfering substances, the distillation method should be used.

DIRECT NESSLERIZATION

Elimination of Interfering Substances

Proteins, sulfur dioxide, sulfides, magnesium, and calcium produce turbidity in the presence of the nessler reagent and must be removed before direct nesslerization can be accomplished. It is well to determine by preliminary or spotting tests (q.v.), which, if any, of the interfering substances are present and select from the following procedures those required to remove the interfering substances found.

Procedure

1. Place exactly 100 ml. of the sample in a 100 ml. sedimentation tube (see section on suspended matter), a tall slender glass cylinder or a tall nessler tube.
2. If proteins and colloidal material are present, add 1 ml. of 10 percent copper sulfate solution and 1 ml. of 50 percent sodium hydroxide solution to the sample. Mix thoroughly by rotation. The bluish-white precipitate of copper hydroxide will clear the sample of proteins and suspended matter by flocculation (Phelps, 1904). Put aside until precipitate has settled.

3. If sulfides or sulfur dioxide are present, use 1 ml. of 10 percent lead acetate solution instead of copper sulfate solution and proceed as in 2 (Phelps, 1904).

4. If calcium and magnesium are present, two alternative procedures can be used to eliminate interference. Both are good.

a. Add 0.5 ml. of 50 percent potassium-sodium tartrate solution to a 100 ml. sample. Rotate and proceed at once with the nesslerization. If other interfering substances are present, remove them first and then add 0.2 ml. of the tartrate solution to a 10 to 25 ml. portion of the cleared sample immediately before nesslerization (Kolthoff and Sandell, 1938).

b. Add 5 ml. of 10 percent di-sodium phosphate to a 100 ml. sample, mix by rotation and centrifuge portion required for nesslerization (Nau, 1943).

NESSLERIZATION

After the interfering substances have been removed, measure a definite quantity, 5 to 25 ml. of the cleared sample, into a 100 ml. (or 50 ml.) nessler tube and make up to mark, i.e. to 100 or 50 ml., with ammonia-free distilled water. Add 2 ml. of nessler reagent, mix by rotation and put aside in subdued light for 10 minutes. Compare with standards in tubes of same capacity and length, or pour into a cell and read in photelometer. After the determination is completed, make necessary corrections for dilution during the elimination of interfering substances and for the aliquot which was nesslerized.

CAUTIONS

Nesslerized samples will often become turbid if too warm even though the interfering substances have been removed. It is well to cool both sample and nessler reagent to 18° C. or lower whenever possible. An ice water bath for samples, reagents and standards is desirable in hot weather.

Do not filter sample either before or after adding any of the reagents in the procedures required for the elimination of interfering substances. If precipitates form, let them settle out or centrifuge the sample.

DISTILLATION METHODS

In some cases, especially where small quantities of ammonia are involved and maximal accuracy is important, the distillation method should be used. Although this procedure is not adaptable to field work, in the laboratory this method gives good results if various cautions are noted. Boil distilled water in the distillation apparatus until all parts are freed of ammonia. Then distill a 500 ml. sample to which 10 ml. of the phosphate buffer solution has been added to assure, during the boiling, the maintenance of a pH of about 7.4, the optimal value for quantitative recovery of ammonia. Collect the first 200 ml. of distillate, take an aliquot part and nesslerize as previously described.

PREPARATION OF STANDARDS

Prepare a graded series of Nessler tubes (10 to 20) containing exact quantities of standard ammonium chloride solution varying from 0.1 ml. through 5 ml. Add sufficient ammonia-free distilled water to each tube to bring the solution up to the 100 ml. mark, nesslerize, wait 10 minutes and the series is ready to use for several hours. Compare the unknown with these standards, reading through the tubes lengthwise against a white surface reflecting daylight or a pale-blue light. One milliliter of the ammonium chloride solution contains 0.01 mg. of nitrogen. Due to the difficulty in preparing nessler's reagent and the wide variation in the quality of distilled waters, these freshly prepared standards made with the same nessler's solution and distilled water used in the preparation of the samples are preferred to permanent standards.

Permanent standards, however, have the definite advantage of saving of time. They may be prepared according to the table given by Jackson (1900), but as they are only approximate, they should be checked with each newly prepared supply of nessler's reagent, and by the particular analyst who is to use them, due corrections being made by addition of traces of the proper solutions of potassium chloroplatinate and cobaltous chloride to produce matching tints. Otherwise, results will be incorrect.

If a photelometer is available, the determinations can be made with greater accuracy than by visual comparison. A blue filter should be used and a standard curve prepared from readings of nesslerized samples containing known quantities of ammonia. The best results with unknowns are realized if a rigid time schedule is followed for each sample so that all are read the same number of minutes after nesslerization. If any precipitate forms during nesslerization, the preparation must be rejected. The standard curve should be checked with each new supply of nessler reagent.

ORGANIC NITROGEN

Effluents containing sewage, wastes from slaughter houses and tanneries, and various chemical processes, frequently contain nitrogen in combinations other than ammonia. Although these nitrogenous compounds may not be toxic to fishes, eventually, if the waters are stagnant and warm, much of this nitrogen may be converted to ammonia. Therefore, the organic nitrogen offers a potential hazard which should be measured and evaluated in most organic pollution problems.

METHODS

KJELDAHL METHOD (KJELDAHL, 1883)

This procedure is based on the principle of breaking down organic nitrogen into ammonia, which is distilled off and nesslerized.

PROCEDURE

1. Boil 500 ml. sample in an open Kjeldahl flask until about

one-half the solution has evaporated carrying the ammonia with it.

2. Add 5 ml. of concentrated nitrogen-free sulfuric acid and some boiling chips or beads (soft beads must not be used), to the sample remaining in the flask. Shake well and digest with heat until white fumes appear. The solution should be a pale straw-yellow or colorless and free from granules of carbon.

3. Cool and make up to 250-300 ml. with ammonia-free water. Add 50 percent sodium hydroxide until the mixture is alkaline to phenolphthalein.

4. Distill to one-half volume, nesslerize the distillate, and compare it with the standards as described under ammonia.

Water carrying a heavy load of organic material should be treated with 10 ml. of sulfuric acid and 1 ml. of 10 percent copper sulfate solution (as a catalyst) to assure complete digestion. In obstinate cases, 5 grams of potassium or sodium sulfate may be added to raise the boiling temperature. Even with this treatment, the authors have observed occasional samples containing residual pieces of carbon.

DIRECT NESSLERIZATION

As the Kjeldahl method is time consuming and requires a large sample, a procedure used by clinicians requiring a small sample and no distillation has been adapted to pollution studies. This method is based on Koch and McMeekin's micro-Kjeldahl method (1924), Wong's (1923) modification of Folin and Denis's (1916) method, and suggestions by Peters and Van Slyke (1932), and Hoffman (1941).

PROCEDURE

1. Add 1 ml. of 50 percent sulfuric acid to not more than 10 ml. of the water sample in a 200 × 25 mm. pyrex test tube. Place a quartz bead in the tube and heat until copious white fumes appear.

2. Cool for 1 minute and add 2 drops of saturated potassium persulfate solution (or 30 percent hydrogen peroxide up to 1 ml. if needed) and heat for 2 to 5 minutes after the white fumes again have appeared.

3. Cool to room temperature and make up to 100 ml. with ammonia-free distilled water.

4. Add 1 to 2 drops of 10 percent copper sulfate solution and one-half ml. of 50 percent sodium hydroxide. Allow the flocculant precipitate to settle, and decant 50 ml.

5. Nesslerize the 50 ml. with 2 ml. of nessler's reagent and read in the photelometer (using a blue filter) after 10 minutes. Calculate the results from the standard curve as described.

REAGENTS FOR NITROGEN DETERMINATION

Ammonia-free water. — Re-distill distilled water acidified with 2 ml. sulfuric acid per liter. The ammonia will not be lost from the acid solution. Keep tightly sealed in a glass-stoppered bottle.

Nessler reagent, regular method. — Dissolve 50 grams of potassium iodide in 35 ml. of cold ammonia-free distilled water. Add saturated mercuric chloride solution slowly until a slight precipitate persists. This step is very important. Add 400 ml. of a 50 percent solution of potassium hydroxide. Dilute to 1 liter, allow to settle at least overnight. Decant and store the clear solution. Two ml. of this solution are required per 100 ml. of sample.

Koch and McMeekin's Nessler reagent. — Dissolve 22.5 grams of iodine in 20 ml. of water containing 30 grams of potassium iodide. Add 30 grams of pure metallic mercury and shake the mixture well, keeping it cool by partly immersing the flask frequently in tap water. Continue until the supernatant fluid has lost all of the yellow color resulting from iodine. Decant the supernatant fluid and test a few drops with a small quantity of starch solution. A very small amount of iodine should be present as indicated by a faint blue reaction. If no blue color develops, add iodine cautiously until a blue color is produced. Otherwise the solution may contain mercurous compounds that may cause turbidity with ammonia solutions. Dilute to 200 ml., mix, and add to 975 ml. of accurately prepared 10 percent sodium hydroxide solution. Mix thoroughly and put aside for 12 hours or more. Decant and store clear fluid. Ten ml. of this solution are required per 100 ml. sample.

Copper sulfate, 10 percent solution. — Dissolve 20 grams of c.p. copper sulfate crystals, $CuSO_4.5H_2O$ in sufficient ammonia-free distilled water to make 200 ml.

Sodium hydroxide, 50 percent solution. — Dissolve approximately 50 grams of pure sodium hydroxide in sufficient ammonia-free distilled water to make 100 ml.

Lead acetate, 10 percent solution. — Dissolve 10 grams of lead acetate $Pb(C_2H_3O_2)_2.3H_2O$, in sufficient distilled water to make 100 ml.

Standard ammonium chloride stock solution. — Weigh out 3.818 grams of pure ammonium chloride, NH_4Cl, and add sufficient ammonia-free distilled water to make 1 liter. Dilute 10 ml. of the stock solution with ammonia-free distilled water to 1 liter. One ml. of this solution contains 0.01 mg. of nitrogen.

Potassium-sodium tartrate solution. — Dissolve 50 grams of pure potassium-sodium tartrate (Rochelle salt, $KNaC_4H_4O_6.4H_2O$) in sufficient ammonia-free distilled water to make 100 ml.

Phosphate buffer solution, approximately pH 7.4. — Dissolve 14.3 grams of monobasic potassium phosphate KH_2PO_4, and 90.15 grams of di-basic potassium phosphate, K_2HPO_4, in sufficient ammonia-free distilled water to make 1 liter.

Concentrated sulfuric acid, c.p. — Specific gravity 1.84.

Sulfuric acid. — A 50 percent solution (by volume). Add cautiously 50 ml. of nitrogen-free concentrated sulfuric acid to 50 ml. of ammonia-free distilled water.

Phenolphthalein indicator solution. — A 0.5 percent solution in 50 percent ethyl alcohol.

Potassium persulfate, saturated solution. — Shake up about 7 grams of low-nitrogen potassium persulfate in 100 ml. of ammonia-free distilled water. Some of the persulfate will remain undissolved in the bottom of the bottle and will replace the small amount lost by decomposition.

Di-sodium phosphate. — Dissolve 10 grams of monoacidic sodium orthophosphate, $Na_2HPO_4.12H_2O$, in distilled water to make 100 ml.

Hydrogen peroxide. — Strong solution, 30 percent.

Starch solution, 1 percent. — Make a thin paste with 1 gram of potato starch in cold water and add it to 100 ml. of boiling distilled water and stir. Allow to cool. A few drops of chloroform will preserve this solution for several weeks.

IRON DETERMINATIONS

Iron occurs in many natural waters but because of its chemical characteristics usually the amount is small ranging from 0 to 2 p.p.m. in well-aerated unpolluted waters. Little ferric iron remains in solution unless the water is distinctly acidic and dissolved ferrous iron changes rather rapidly to ferric iron and then leaves the water, if there is ample dissolved oxygen. In the deeper portions of lakes and impoundments, iron may be much higher and may seriously affect the dissolved oxygen supply. In a South Dakota lake lying in a shale formation, the authors have found more than 10 p.p.m. of iron at the depth of 50 feet in water having almost no dissolved oxygen and less than 0.5 p.p.m. at the surface of this same lake where the water was well aerated. Iron may also be high, exceeding 100 p.p.m. in small streams receiving the acidic drainage from coal mines and pyrite-bearing formations. Numerous industrial effluents contain considerable quantities of iron. The presence of more than 1 or 2 p.p.m. of iron usually points to polluted water or to conditions which may be unfavorable to fishes. However, this statement refers to iron in solution.

Many streams carry much more iron in suspension than in solution. Insoluble or poorly soluble compounds of iron are numerous and are often found in silt, mud and various forms of suspended matter carried by moving waters where they are of little consequence to the biota of the stream. In reporting iron determinations, therefore, it is necessary to state whether the suspended matter was removed from the water before the analysis was made.

METHODS

Considering the amounts to be detected and the restrictions of field work, the colorimetric determination of iron by thiocyanate is perhaps the most serviceable for water studies. Although prepared samples for iron determinations can be returned to the laboratory and satisfactory analyses for total iron made months after the samples were collected, it is often desirable to make iron determinations in the field to separate the ferrous and ferric components.

FERRIC IRON

Place a 75 ml. sample, carrying not to exceed 10 p.p.m. of ferric iron, in a 100 ml. volumetric flask and add 1 ml. of concentrated hydrochloric acid, and 20 ml. of 1.5 M potassium thiocyanate solution. Make up to 100 ml. with distilled water.

Mix quickly and read at once in a photelometer using a green screen having a maximal transmission near 4800 A.U. Evaluate reading from curve prepared with photelometer readings from solutions of known iron content using standard iron solution.

LIMITATIONS

The amount of ferric iron must not exceed 10 p.p.m. If more is present, dilute sample accordingly. It may be necessary to run several preliminary tests if the iron content is high before a satisfactory dilution is found.

If ferrous iron is also present, the sample must be handled with minimal agitation to prevent aeration which might oxidize the ferrous iron to the ferric stage. As soon as the acid is added, this change is retarded.

If suspended matter is present, it should be centrifuged out and only the clear water used to avoid addition of iron from the suspended material.

This method is unreliable if oxalates are present or 30 p.p.m. or more of fluorides (Woods and Mellon, 1941). However, as oxalates are rarely found in natural waters even if polluted, and as 30 p.p.m. of fluorides is a very high concentration even for waters carrying oil-field waste waters, these two sources of interference, although they must be remembered, can usually be disregarded.

TOTAL IRON

Evaporate a 100 ml. sample containing not to exceed 10 p.p.m. of iron to dryness and ignite gently if organic material is present. Cool.

Add 1 ml. of 50 percent hydrochloric acid and 2 ml. of distilled water. Heat for 10 minutes on a boiling water bath but do not evaporate to dryness. Cool.

Add 10 ml. of distilled water and one drop of 0.1 N potassium-permanganate solution. If the color disappears, add more permanganate cautiously until a pale pink color persists for at least 5 minutes.

Transfer the solution to a 100 ml. volumetric flask. Wash evaporating dish several times into the flask with a few milliliters of distilled water. Add 1 ml. of concentrated hydrochloric acid and 20 ml. of 1.5 M potassium thiocyanate solution. Make up to 100 ml. with distilled water, mix quickly and read at once in a photelometer using a green screen.

FERROUS IRON

The amount of ferrous iron can be computed by deducting the ferric iron as determined under Ferric Iron (p. 72) from the total iron, that is, the ferric iron plus the ferrous iron which was oxidized to the ferric state, as determined in the section immediately preceding.

LIMITATIONS

The same limitations apply to this procedure as to that on p. 72. The details of the thiocyanate method are discussed by Sandell (1944).

REAGENTS

Potassium thiocyanate, 1.5 M solution. — Dissolve 14.57 grams of reagent quality potassium thiocyanate, KSCN, in distilled water to make 100 ml.

Potassium permanganate, 0.1 N solution. — Dissolve 0.32 grams of potassium permanganate, $KMnO_4$, in distilled water to make 100 ml.

Hydrochloric acid. — Concentrated, reagent quality, specific gravity 1.19.

Ferric ammonium sulfate for standard iron solution. — Dissolve 0.7022 grams of reagent quality crystalline ferrous ammonium sulfate, $Fe(NH_4)_2(SO_4)_2.6H_2O$ in 100 ml. of distilled water and 20 ml. of concentrated sulfuric acid. Heat to about 70° C. and add potassium permanganate solution until the iron has been oxidized to the ferric stage. The persistance of a pale pink color will mark this end point. Make up to 1 liter with distilled water. One ml. of this solution carries 0.1 milligram of iron.

MANGANESE

Compounds of this element occur in many natural waters. Wiebe (1930) reported 0.044 to 0.128 p.p.m. in the surface waters and 0.072 to 0.120 p.p.m. in waters near the bottom of the Mississippi River, and Ohle (1934) states that manganese is more abundant than iron in some of the north German lakes. Platner (1945) found the manganese content of waters from several western tributaries of the Mississippi River to lie between 0.05 and 0.22 p.p.m.

METHOD

For water samples the colorimetric determination of the manganese after oxidation to permanganate is satisfactory. The sequence presented here is a modification of the method of Willard and Greathouse (1917).

PROCEDURE

1. Place a 100 ml. sample in a 250 ml. Erlenmeyer flask and add 5 ml. (up to 10 ml. if considerable iron be present) of 85 percent phosphoric acid, and 0.5 to 2.5 grams of potassium periodate.
2. Boil mixture for 3 minutes.

3. Cool, transfer to a 100 ml. volumetric flask, and make up to 100 ml. with distilled water.

4. Read in photelometer using a green screen. Evaluate results from curve prepared with standardized potassium permanganate.

LIMITATIONS

This procedure gives good results for manganese in excess of 0.1 p.p.m. If the manganese content of the water is below that value, the sample should be concentrated.

Iron interferes with the reaction unless phosphoric acid be present, and the amount of this acid used should be adjusted accordingly.

Periodate must be present in a slight excess beyond that required to oxidize the manganese. The amount of this compound needed will vary, therefore, with the amount of manganese.

REAGENTS

Phosphoric acid. — 85 percent, c. p.

Potassium periodate. — Reagent quality crystals.

Potassium permanganate. — Use a very weak solution and standardize against a carefully prepared potassium oxalate solution.

COPPER

Copper is a frequent pollutant in streams receiving run-off waters or wastes from mining and industrial areas. Copper salts are used extensively in agricultural sprays and are employed occasionally as algicides in ponds and lakes. The toxicity of copper compounds for fishes and other aquatic life varies considerably with aquatic conditions, as copper is precipitated readily by carbon dioxide and carbonates and is removed, therefore, rather rapidly from hard waters. Consequently, the minimal lethal dose of copper sulfate for freshwater fishes has been reported as ranging from 0.3 to 10.0 p.p.m. (Ellis, 1937).

The specific action of copper salts on the mucous covering of the gills of fishes precipitates a coating on the gills which interferes with respiration. This is the effect most frequently noted in heavy copper pollution. The toxic action of copper on many plankton organisms and bacteria must also be considered in sustained copper pollution at low concentrations.

METHOD

The sodium diethyldithiocarbamate method has proven very satisfactory for both field and experimental water studies.

PROCEDURE

1. Place a 50 ml. sample in a 100 ml. glass-stoppered separatory funnel and acidify with hydrochloric acid using methyl orange as the indicator.

2. Add 5 ml. of 20 percent ammonium citrate solution, neutralize with ammonium hydroxide and add 2 ml. of ammonium hydroxide in excess of that required for neutralization.

3. Add exactly 5 ml. of carbon tetrachloride and 1 ml. of 0.1 percent diethyldithiocarbamate solution. Stopper funnel and shake for 2 minutes.

4. Return funnel to rack and after the tetrachloride has separated draw it directly into a cell, avoiding all droplets of water. Read in a photelometer using a green screen.

REAGENTS

Sodium diethyldithiocarbamate. — Dissolve 0.1 gram of pure sodium diethyldithiocarbamate, $Na(C_2H_5)_2NCS_2$ in distilled water to make 100 ml. Store in brown glass-stoppered bottle. Do not use after three weeks.

Ammonium citrate, 20 percent solution. — Dissolve 20 grams of ammonium citrate, $(NH_4)_3C_6H_5O_7$, in distilled water to make 100 ml.

Carbon tetrachloride. — CCl_4, c.p.

Methyl orange. — Dissolve 0.05 gram of methyl orange in distilled water to make 100 ml.

Hydrochloric acid. — c.p.

Standard copper solution. — Dissolve 0.393 gram of bright clean crystals of reagent quality copper sulfate, $CuSO_4.5H_2O$, n 500 ml. of distilled water to which 20 ml. of concentrated sulfuric acid have been added. Make up to 1 liter with distilled water. Dilute 25 ml. of this stock solution to 250 ml. with distilled water when needed. One ml. of the dilute solution carries 0.01 milligram of copper.

ZINC

The toxic action of zinc compounds even in small quantities has been established for various aquatic animals and plants, and as zinc in several forms is a regular component of many mine wastes and industrial effluents, this element must be regarded as among the more dangerous pollutants. However, there s increasing evidence that small quantities of zinc are required by aquatic animals. The frog is known to store appreciable quantities of zinc in its skin (Brooks,1936) and the authors have ound this metal in the integument of some cyprinids.

Zinc compounds seriously affect the gills of many fishes causing increased secretion of mucus and the production of metal-organic combination in and on the gills which causes death by respiratory difficulty and anoxia.

The gill condition develops promptly and is very evident in fishes exposed to 100 p.p.m. or more of zinc compounds but much smaller amounts produce the same condition over a longer period of time. Newton (1944) reports that as little as 0.3 p.p.m. of zinc is toxic to some fresh-water fishes. The authors have observed similar effects in streams polluted with zinc-mine waste and with zinc sulfate from electrolytic zinc plants. In one eastern stream, the entire bottom fauna was eliminated by small quantities of soluble zinc discharged from a cellulose products plant.

Unfortunately the determination of small quantities of zinc in water samples is rather difficult.

METHOD

The well-known reaction of dithizone with heavy metals to produce colored compounds is the basis of this method. Although the substances interfering with zinc usually are not found in most water samples from streams, the suppression of these substances is accomplished by the use of sodium thiosulfate as given by Bright (1934).

PROCEDURE

1. Place 100 ml. of sample water in a suitable separatory funnel and add 10 ml. of 10 percent sodium citrate solution and 1 ml. of ammonium hydroxide. (If the sample is acidic, sufficient ammonium hydroxide must be added to make the mixture definitely but not strongly alkaline).
2. Add 10 ml. of 0.01 percent dithizone in carbon tetrachloride and shake for 2 to 3 minutes.
3. Separate the carbon tetrachloride, place in a second separatory funnel, and add 20 ml. of 0.01 N hydrochloric acid and 10 ml. of distilled water. Shake well.
4. Separate the aqueous fraction and place in a separatory funnel. Make up to approximately 50 ml. with distilled water and adjust acidity to pH 4.4 using methyl orange as an external indicator.
5. Add 5 ml. of 25 percent sodium thiosulfate solution and exactly 10 ml. of 0.01 dithizone in carbon tetrachloride.
6. Shake well for 2 to 3 minutes. Separate tetrachloride fraction and read in photelometer using a green screen.
7. Evaluate results from chart of readings of samples prepared by using known amounts of zinc treated by the same routine.

LIMITATIONS

The amount of zinc in the sample should lie between 1 and 5 gamma. If more is present, dilute a fresh sample with the distilled water, if less, concentrate a fresh sample which has been slightly acidified with hydrochloric acid.

It may be desirable to use more or less carbon tetrachloride reagent with some samples.

All reagents must be tested zinc-free or a reagent blank must be carried in parallel.

REAGENTS

Sodium citrate, 10 percent solution. — Dissolve 100 grams of reagent quality sodium citrate, $Na_3C_6H_5O_7.5H_2O$, in distilled water to make 1 liter.

Ammonium hydroxide. — Reagent quality.

Dithizone reagent, diphenylthiocarbazone. — Dissolve 0.01 gram purified reagent quality dithizone in 100 ml. of pure carbon tetrachloride.

Sodium thiosulfate, 25 percent.—Dissolve 250 grams of reagent quality sodium thiosulfate, $Na_2S_2O_3.5H_2O$, in distilled water to make 1 liter.

Hydrochloric acid. — 0.01 N solution.

SULFATES

Sulfates are found in most natural fresh waters, excepting some mountain streams near their snow sources, a very few "soft" lakes and certain spring fed streams. Sulfates, particularly magnesium, calcium and sodium sulfates can be listed, therefore, as one of the expected groups of compounds tolerated by fishes in concentrations up to 300 p. p. m. or more without marked effects. Ellis (1940) reports from 100 to 274 p. p. m. of sulfates throughout the year in the waters of Elephant Butte Reservoir, which impoundment supports a mixed fauna of the common warm-water fishes, and Platner (1945) in a recent survey of the Mississippi found sulfates in that stream ranging from 10 to 90 p. p. m.

Sulfates are also components of many industrial wastes, and of waters draining various natural formations as pyrite bearing strata, alkali flats, and geyser fields, so the determination of sulfates, which is reasonably simple, provides a good tracer in many water-quality studies in addition to making possible the evaluation of any special significance which the sulfates may have in the waters under consideration.

METHOD

The benzidine method for the determination of sulfates (Owen, 1936) is both rapid and sufficiently accurate for water quality studies.

PROCEDURE

1. To a 50 ml. sample, add 1 ml. of concentrated hydrochloric acid, or more if the water is strongly alkaline, to adjust the pH to near pH 2.75.
2. Add 10 ml. of benzidine hydrochloride solution and mix well.
3. After 10 minutes, filter using acid-washed, sulfate free filter paper of fine texture to retain the precipitate.
4. Test filtrate with a few drops of benzidine solution to determine whether all sulfates have been removed. If the filtrate becomes cloudy on the addition of benzidine, add more reagent and refilter. Discard final filtrate.
5. Wash precipitate on filter paper with water saturated with benzidine sulfate (p. 78).
6. Transfer washed filter paper to a 250 ml. Erlenmeyer flask, add 25 ml. of distilled water and break up filter paper with glass stirring rod.

7. Heat sample just to boiling point to drive off any carbon dioxide present.

8. Titrate with standardized N/50 sodium hydroxide solution to phenolphthalein endpoint.

LIMITATIONS

In average water samples this method gives good results with as little as 3 p. p. m. of sulfate. If less than 3 p. p. m. of sulfate are present, it is advisable to concentrate the sample. An excess of the benzidine reagent is desirable as this excess holds the benzidine sulfate out of solution.

Benzidine is most effective in precipitating sulfates in strongly acid solution at or near pH 2.75, (Owen, 1936). Effort should be made to adjust the sample to this degree of acidity. Phosphates and chloride both interfere with the benzidine method, but the amounts of these compounds present in average water samples do not produce serious errors. In removing the acid from the precipitate of benzidine sulfate on the filter paper before the alkaline titration, it is desirable to use distilled water saturated with benzidine sulfate.

REAGENTS

Benzidine hydrochloride reagent. — Dissolve 11.2 grams of benzidine hydrochloride in one percent hydrochloric acid to make 500 ml.

Wash water for benzidine sulfate precipitate. — Precipitate the sulfate from a small amount of sodium sulfate solution with the benzidine reagent. Filter and wash precipitate with distilled water on filter paper until the filtrate is acid-free. Transfer the washed precipitate to 500 ml. of distilled water. Keep in a glass-stoppered bottle. There should be undissolved benzidine sulfate on the bottom of the bottle at all times.

Sodium hydroxide, N/50 solution. — Dissolve 0.8 gram of pure sodium hydroxide in distilled water to make 1 liter. Standardize against a known solution of sulfuric acid to establish the sulfate equivalent for the hydroxide solution.

Hydrochloric acid. — c.p.

SULFIDES, SULFITES, AND OTHER NON-SULFATE SULFUR COMPOUNDS

These various sulfur compounds are often found in polluted waters and waters near the bottom of deep lakes and impoundments. As the chemical separation of the individual compounds is often very difficult, the determination of these sulfur compounds collectively is usually sufficient. The procedure consists in transforming this non-sulfate sulfur into sulfate and determining it as such.

PROCEDURE

1. Determine the sulfates in an untreated sample by the benzidine method.

2. Adjust the alkalinity of a second sample with sufficient strong sodium hydroxide to approximately pH 11.
3. Add 0.5 gram (or more depending upon the amount of organic material and sulfur compounds present) of crystalline sodium nitrate to each 100 ml. of sample.
4. Evaporate to dryness and ignite gently.
5. Take up residue in 20 ml. of distilled water and neutralize cautiously with hydrochloric acid.
6. Determine sulfates by benzidine method.
7. The difference between the sulfates in the treated and untreated samples gives non-sulfate sulfur, as sulfates, from which the sulfur alone can be computed if desired.

PHOSPHATE DETERMINATIONS

Phosphates are not determined routinely in water-quality studies as these compounds are not toxic in the quantities usually found in natural waters and as a rule vary in lakes and streams with the season, as noted by Birge, Juday, and Kemmerer (1927). However, phosphate determinations are often necessary, because small amounts of phosphates are essential to both aquatic plant and animal life, and phosphates may be involved in some types of pollution.

The authors have found the method which depends on the development of a strong blue color by acidified phosphomolybdate solution when reduced with stannous chloride to be very satisfactory for phosphate determinations in water-quality studies. This ceruleomolybdic method as described by Deniges (1920) has been altered and adapted in various ways but the modification of Florentine (1921) has been selected because this procedure has been used successfully in several outstanding studies of American fresh waters.

METHOD

To develop a color in a test solution, add 2 milliliters of the acidified ammonium molybdate reagent and 3 or 4 drops of stannous chloride solution. Mix well. The full blue color, if phosphates are present, develops in from five to ten minutes and fades at the rate of about one percent per hour during the next 25 hours. For greatest accuracy and especially in establishing the curve from standard solutions, the preparation of samples should be timed so that the photelometric readings are made exactly six, seven, or eight minutes after the stannous chloride is added. This specified time limit should be observed in all subsequent readings to be translated by the curve so established.

The blue color developed during the phosphomolybdate reduction with stannous chloride can be read conveniently in a photelometer using an orange-yellow filter. From a series of dilutions of the standard phosphate solution, it is possible to establish a curve from which photelometric readings of the blue color developed in water samples may be translated into parts per million phosphorous.

The exact measurement of the reagents is of primary importance since there is some color developed in a water blank containing no phosphates. Two groups of substances other than phosphates also give color reactions with this combination of reagents and may provide, therefore, interfering colors. If dissolved silicon (in the form of H_2SiO_3) is present in concentration greater than 49 milligrams per liter, correction must be made for the presence of this compound before the phosphates can be read correctly. However, such a concentration of silicon is rare in most natural waters excepting some from hot springs and geyser fields. A more likely source of interference by silicon comes from the possible contamination of the reagents used in the phosphate determinations if these reagents are stored in soft glass of poor quality. It is desirable, therefore, to store the reagents used in pyrex glass. Soluble arsenic compounds also cause interference in the phosphate determination because arsenic develops a similar blue color with these reagents. The authors have not found arsenic to be extracted from pyrex glass in sufficient quantity, however, to cause any discrepancy from that source. However, check should always be made to correct for any color originally in the water sample, that is the untreated sample should be read in the photelometer using the orange-yellow light filter and whatever deflection is noted should be subtracted from the deflection produced by the sample after treatment with the reagents.

Samples for dissolved phosphate should not be held more than one to three hours before determinations are made if very accurate determinations are desired unless these samples are very carefully filtered through high grade filter paper capable of retaining very small particles, because the phosphorous of the nannoplankton may be added to that already in solution in the water if these tiny organisms die and undergo dissolution.

In the 88 Wisconsin Lakes studied by Birge, Juday, and Kemmerer (1927) the dissolved phosphorous ranged from 0.0 to 0.75 p. p. m., with the majority of values lying between 0.003 and 0.012 p. p. m. In Elephant Butte, Ellis (1940) found 0.003 to 0.015 p. p. m. of phosphates and the same author reports values between 0.030 to 0.041 p. p. m. from four localities in the Rio Grande.

Total phosphorous, including that contributed by the nannoplankton and by any nonphosphate compounds of phosphorous which may be present, may be determined by the phosphate method at any time after the following treatment.

PROCEDURE

1. A 100 ml. sample is evaporated to 5 to 10 ml. volume after the addition of 0.2 ml. of concentrated sulfuric acid.
2. To the concentrate 3 ml. of concentrated c.p. nitric acid are added and the evaporation continued until the sulfuric acid begins to liberate white fumes.
3. Cover the evaporating dish and redilute with 5 to 10 ml. of distilled water.
4. Add 3 ml. of concentrated c.p. hydrochloric acid and evaporate a second time until the first white fumes appear. Do

not continue the evaporation beyond this point but cover immediately and make up to 100 ml. volume with distilled water. This preparation may be analyzed for phosphates by the procedure outlined.

REAGENTS

Sulfuric acid, 50 percent solution. — This is made with sufficient accuracy by adding 45 ml. of concentrated c.p. sulfuric acid (specific gravity 1.84) slowly to 50 ml. of distilled water. The solution is cooled and additional distilled water added to make exactly 100 ml. This reagent may be kept indefinitely as a stock solution.

Ammonium molybdate, 10 percent solution. — This solution is prepared by dissolving 10 grams of c.p. ammonium molybdate in 80 ml. of distilled water and making up to 100 ml. volume with distilled water. This solution may be kept in a dark bottle for several months with safety.

Acidified ammonium molybdate reagent. — This reagent must be prepared fresh at the time the analyses are to be made but if poured immediately into a dark brown bottle, it will be safe for use over a period of some eight hours. It is prepared by adding 15 ml. of 50 percent sulfuric acid solution to 5 ml. of the 10 percent ammonium molybdate solution.

Stannous chloride solution. — This is prepared by dissolving 2.15 grams of good stannous chloride ($SnCl_2.2H_2O$) in 20 ml. of concentrated c.p. hydrochloric acid. When the solution is complete, add sufficient distilled water to make 100 ml. and place a small piece of mossy metallic tin in the bottle. This solution will keep for weeks if mossy tin be present.

Standard phosphate solution. — This is prepared from monobasic potassium phosphate (KH_2PO_4) which has been dried over sulfuric acid. Dissolve 4.388 grams of the prepared monobasic potassium phosphate in phosphate-free distilled water to make one liter. This solution should be placed in a brown bottle and the ground glass stopper carefully covered so that neither foreign material nor concentrate will be added when the solution is used for standardizing purposes. One milliliter of this solution contains one milligram of phosphorous.

FLUORIDES

Fluorides often identify waters from deep strata for, as pointed out by Tageeve (1942), fluorides are frequently found in salt waters from oil wells and in waters from areas which have been subjected to recent vulcanism. However, fluorides occur in many widely scattered localities, are components of several industrial wastes, and are used in wood preservatives.

The immediate effects of fluorides on fishes are apparently not severe as goldfishes live for 60 to 120 hours in waters containing 1,000 p.p.m. of sodium fluoride and ten days or longer in 200 p.p.m. Little has been reported concerning the chronic effects of fluorides on fishes. The authors have observed that the hatching of fish eggs carried in water containing 1.5 p.p.m.

of fluoride was delayed a week or ten days beyond the hatching of comparable eggs in water containing no fluoride, and that the hatch in the fluoride water was poorer. It is well established that fluorides disturb both calcium and phosphorous metabolism in mammals (McClure and Mitchell, 1931) and marine fishes are known to store fluorine in their tissues (Sognnaes, 1941).

In view of the interest in the effect of fluorides on man and other mammals, as well as possible effects on fishes, a field method for fluorine is included here.

METHOD

The bleaching of alizarine color by fluorides in the presence or zirconium salts as noted by DeBoer (1924) is the basis of the method currently used by many analysts for the determination of fluorides in water. The authors have adapted the sequence described by Elvove (1933) for use with a photelometer and have found the method serviceable in the field.

PROCEDURE

1. Place a 50 ml. sample in a 100 ml. glass-stoppered bottle and add 5 ml. of 5 N hydrochloric acid and 1 ml. of the dilute alizarine-zirconium reagent. Put aside in subdued light for 20 minutes.
2. If the pink color has faded completely so that the solution is either colorless or has a yellowish cast, too much fluoride is present and a new preparation must be made. Dilute the sample water with distilled water and repeat original procedure.
3. When a treated sample is obtained which retains some (not necessarily all) of its pink color for 20 minutes, put it aside, protected from strong light, for 18 hours.
4. Read in photelometer using a green screen. Evaluate reading from a standard curve prepared by plotting the readings of samples containing known amounts of fluoride. Use a deep cell as the color is quite pale.

LIMITATIONS

Although many substances interfere with this method, if the strongly acid solution is used as outlined above, Suckling (1943) reports that calcium, magnesium, sodium, bicarbonates, sulfates and chlorides must exceed 250 p. p. m. to disturb the reaction; that phosphates, copper, and iron must exceed 5 p. p. m.; that 10 parts per million or more of either manganese or zinc will augment the bleaching reaction and give values too high; and that aluminum, although not commonly found in water samples, will cause the readings to be too low if 0.5 p. p. m. or more is present. It is well, therefore, before making the test for fluorides to have checked these various sources of interference.

REAGENTS

Hydrochloric acid, 5 N solution. — Make up 520.8 ml. of concentrated hydrochloric acid to 1 liter with distilled water.

Stock zirconium solution. — Dissolve 0.5 gram of zirconium oxychloride, $ZrOCl_2.8H_2O$, in distilled water to make 100 ml. Keep in a brown glass-stoppered bottle. Casares and Casares (1930) and Jordan and Frary (1938) used zirconium nitrate, $Zr(NO_3)_4.5H_2O$, in their studies of the fluorine content of mineral waters and water supplies.

Stock alizarine solution. — Dissolve 0.1 gram of sodium alzarine monosulphonate in distilled water to make 100 ml. Keep in brown glass-stoppered bottle.

Diluted zirconium-alizarine reagent. — Add 5 ml. of the stock alizarine solution to 5 ml. of the stock zirconium solution very slowly and with much shaking. If the two are combined in reverse order, a precipitate that redissolves only with great difficulty is formed. When the mixture is complete and clear, add 10 ml. of distilled water. This solution must be kept in a brown glass-stoppered bottle and is good for only 24 hours at ordinary temperature.

Standard fluoride solution. — Dissolve 22.1 mgs. of sodium flouride, NaF, in distilled water to make 200 ml. One ml. of this solution contains 0.05 mgs. of fluorine.

CHLORIDES

The determination of chlorides is often important in tracing pollution from oil-well waters and from the effluents of various industries using common salt.

The method used is based on the well-established precipitation of silver chloride in an acidic medium. In most water-quality studies, the chloride content of the water can be obtained with sufficient accuracy by titration of the untreated sample. However, if considerable organic matter or sulfates in excess of 1,000 p. p. m. are present, the titration cannot be made without removing these interfering substances.

PROCEDURES

DIRECT TITRATION

1. Slightly acidify a 100 ml. sample with nitric acid.
2. Add a few drops of potassium chromate solution as an indicator.
3. Titrate over a white surface with standardized silver nitrate solution until the first red color of silver chromate appears.
4. Compute the chloride from the chloride equivalent of the amount of the standardized silver nitrate used.

BACK TITRATION PROCEDURE

1. Slightly acidify a 100 ml. sample with nitric acid.
2. Add silver nitrate from a burette in excess, i.e., until the white precipitate of silver chloride ceases to form. Add additional silver nitrate to an even number of ml.
3. Add two or three drops of ferric nitrate as an indicator.
4. Titrate excess of silver nitrate with sodium thiocyanate solution until red color of the ferric compound appears.

5. Compute the chloride from the standardized sodium thiocyanate in terms of the chloride equivalent of the standardized silver nitrate.

REAGENTS

Silver nitrate reagent. — Dissolve 2.5 grams reagent-quality silver nitrate, $AgNO_3$, in 0.5 percent nitric acid to make 1 liter. Standardize against sodium chloride and store in a brown glass-stoppered bottle.

Sodium chloride standard. — Dissolve exactly 1.6486 grams of pure sodium chloride, NaCl, in distilled water to make one liter. One ml. of this solution carries 1 milligram of chloride chlorine.

Sodium thiocyanate. — Dissolve 2.5 grams of reagent quality sodium thiocyanate, NaSCN, in distilled water to make 1 liter. Standardize against the standardized silver nitrate solution.

Nitric acid. — Concentrated c.p.

Nitric acid. — An 0.5 percent solution.

Potassium chromate. — Dissolve 5 grams of reagent quality potassium chromate, K_2CrO_4, in 50 ml. of distilled water and add a few drops of the silver nitrate solution. Put aside in the dark for 24 hours, filter, and make up the clear yellow solution to 100 ml.

Ferric nitrate. — Dissolve 0.5 gram of reagent quality ferric nitrate, $Fe(NO_3)_3.6H_2O$, in 100 ml. of 0.5 percent nitric acid.

CHLORINE

Chlorine is regularly used in the sterilization of water for human consumption, but this element is highly toxic to many species of aquatic organisms as well as to aquatic bacteria; as little as 1 p. p. m. of free chlorine being lethal for coarse fish (Davis, 1934) and some goldfish (Ellis, 1937). Current usage requires the administration of 0.15 to 1.00 p. p. m. of chlorine in water treatment to leave a residual chlorine of at least 0.10 p. p. m. (Suckling, 1943). More recently, Baty (1945) has advised that the residual chlorine should be 0.40 p. p. m. or more in certain potable waters. It is not surprising, therefore, that fishes and other aquatic animals are often killed in numbers when the residual chlorine in treated waters is allowed to rise only slightly above the values quoted as required in the purification of water supplies.

These chlorine hazards to aquatic life are generally chargeable to overchlorination, either accidental or intentional, of city water supplies, but the sterilization of organic wastes with chlorine, the liberation of chlorine through chemical effluents, and the release of slugs of heavily chlorinated water from swimming pools and industrial impoundments are frequent causes of chlorine catastrophies in natural waters. It is often necessary, therefore, in water-quality study to test for free chlorine.

METHOD

The orthotolidine method based on the formation of a yellow color by chlorine and orthotolidine, and the starch-iodide test in which iodine is liberated from the iodide by the free chlorine are widely used. Both methods have severe chemical limitations due to the interfering action of certain substances frequently found in natural waters and in various effluents. Due consideration must be given to these limitations. These two methods have been reviewed recently by Calvert and others, (1943).

ORTHOTOLIDINE METHOD

This method measures both the free chlorine and that combined in nitrogenous compounds (Calvert and others, 1943), but the color resulting from free chlorine develops quickly so that readings shortly after the mixing of the sample and the reagent will measure free chlorine very largely. If the water contains ferric iron or organic iron compounds in excess of 0.3 p. p. m. of iron, manganic manganese in excess of 0.01 p. p. m., nitrate nitrogen in excess of 0.10 p. p. m., or lignocellulose, this method should not be used. Algae and organic suspended matter should be removed preferably by centrifuging before the test is made.

PROCEDURE

1. Determine the alkalinity (q.v.) of the water.
2. In subdued light or preferably in the dark, add 100 ml. of the sample to 5 ml. of the orthotolidine reagent in 250 ml. beaker, swirling the beaker while the sample is being added to insure complete and rapid mixing. If the sample has an alkalinity greater than 1,000 p. p. m., or is contaminated with sewage or other organic waste, proportionally more of the orthotolidine reagent must be used. The temperature of the sample and the reagent should be as near 20° C. as possible. This is essential so that the sample and reagent should be warmed or cooled accordingly.
3. Transfer a portion of the treated sample to a Nessler tube, comparator tube or cell of photelometer and read within five minutes after the sample is mixed with reagent. Use a blue screen in the photelometer.
4. If Nessler or comparator tubes are used, they must be compared with permanent chlorine standards in tubes of the same bore and length. If photelometer is used, the readings are evaluated from a curve prepared from permanent standards. This procedure has the advantage of eliminating standards from the field equipment.
5. The following conditions must be met if this test is to be reliable (Chamberlain and Glass, 1943).
   a. Interfering substances as noted must not be present.
   b. At least three parts of orthotolidine to one of chlorine by weight must be present.
   c. A ratio of at least 100 ml. of concentrated hydrochloric acid to 1 gram of orthotolidine must be maintained.
   d. The acidity of the treated sample after it has been added to the orthotolidine reagent must be between pH 0.3 and pH 1.3.

e. The sample water must not have an alkalinity greater than 1,000 p. p. m., if 5 ml. of reagent are used per 100 ml. of sample. Proportionally larger amounts of the reagent must be used if the alkalinity is greater.

f. The operation should be carried out in darkness or very subdued light.

ORTHOTOLIDINE REAGENT

Orthotolidine Reagent. — Dissolve 1.35 grams of orthotolidine dihydrochloride in 500-600 ml. of distilled water. Add 150 ml. of concentrated c.p. hydrochloric acid. Make up after mixing to 1 liter with distilled water. Store in a glass-stoppered brown bottle. The reagent will keep for a year or more if not contaminated.

If dihydrochloride is not available, the reagent may be prepared by triturating 1 gram of purified orthotolidine with 5 ml. of 20 percent hydrochloric acid. When the orthotolidine has dissolved, make up to 505 ml. with distilled water, and then add sufficient 20 percent hydrochloric acid to make one liter. Do not add the distilled water until the orthotolidine is dissolved.

PERMANENT STANDARDS

It is recommended that these be purchased from commercial supply houses. However, if desired, they can be prepared in the laboratory (Calvert et al, 1943).

STARCH-IODIDE METHOD

There are two alternatives for this method. If no interfering substances are present, the sample is acidified but if interfering substances such as iron, nitrites, and manganese, are present, the sample must not be acidified. The effect of the interfering substances, ferric iron, manganese, and nitrites is minimal if the water is approximately neutral in reaction but Hallinan and Thompson (1939) report that slightly lower values are obtained in neutral solutions, so that the sample water should be acidified with acetic acid if interfering substances are not present.

PROCEDURE

1. Place 1,000 ml. of sample in a large white evaporating dish if the amount of chlorine is expected to be 1.0 p. p. m. or less. Use a 500 ml. sample if the chlorine content is high (1.0 - 10.0 p. p m.).

2. If no interfering substances are present, add 10 ml. of acetic acid reagent per liter of sample. This should be sufficient to bring the acidity between pH 3.0 and pH 4.0. If interfering substances are suspected, omit the acid and neutralize if necessary.

3. Add 10 ml. of potassium iodide reagent and mix thoroughly. A yellow color will appear if free chlorine is present.

4. Titrate with 0.01 N sodium thiosulfate solution until the yellow color almost disappears.

5. Add 5 ml. of neutral starch solution and complete titration to first complete disappearance of blue color.

6. The amount of thiosulfate required for the titration in milliliters if a one liter sample is used, multiplied by 0.3546 will give the chlorine in p. p. m. If smaller samples are used, the factor must be changed proportionally.

Reagents for Starch-Iodide Method

Acetic acid reagent. — Dilute 50 ml. of glacial acetic acid with distilled water to make 100 ml.

Potassium iodide. — 7.5 percent in 10 percent ethyl alcohol.

Stock sodium thiosulfate. — See dissolved oxygen reagents.

Sodium thiosulfate, 0.01 N solution. — Dilute stock sodium thiosulfate with distilled water to make the desired 0.01 N.

Starch solution. — See dissolved oxygen reagents.

ACETYLENE

Acetylene although present in various effluents is introduced into streams most frequently with waste from acetylene generators. This waste is usually a heavy suspension of slaked lime in water saturated with acetylene gas and various impurities. If this effluent is impounded the supernatant fluid loses most of the dissolved acetylene after a time, but if not properly aerated, the water can hold its load of acetylene gas for many days.

Acetylene has a specific toxic action on fishes much like other anesthetic substances of the methane series (Goodman and Gilman, 1941; Sollman, 1942), and as this gas partly replaces the dissolved oxygen in the water, the toxic effects of dissolved acetylene are often complicated by varying degrees of anoxia. Dissolved acetylene even in properly oxygenated water is a definite hazard to aquatic life and fishes if more than 200 p. p. m. are present. Ellis, Ederstrom, Platner, and Ellis (1943) found goldfishes regularly displayed excitement and incoordination in water carrying 200 to 250 p. p. m. of dissolved acetylene, and died in 24 to 48 hours in water containing 400 p. p. m.; and that brook-trout fingerlings died in 33 hours or less in well-oxygenated water at 10 to 14° C. when approximately 200 p. p. m. of dissolved acetylene was present.

METHOD

Acetylene can be determined by a method adapted from Nifontova (1939) which is based on the reaction of acetylene with silver nitrate as described by Chavastelon (1897 a and b).

Procedure

1. To a measured quantity of 0.01 N silver nitrate solution, add concentrated ammonium hydroxide in the ratio of 4 drops of hydroxide to each milliliter of silver-nitrate solution.

2. From a burette add exactly 20 ml. of the water sample containing acetylene to exactly 10 ml. of the ammoniated silver nitrate solution in a 250 ml. Erlenmeyer flask, rotate the mixture until the gummy silver acetylide aggregates and the remaining fluid becomes relatively clear.
3. Filter through an acid-washed filter paper previously moistened with distilled water and wash both the precipitate and filter paper several times with distilled water, adding the washings to the filtrate.
4. The filtrate, plus washings, is made acid to litmus with strong nitric acid.
5. A few drops of ferric-ammonium alum indicator solution are added to the acid filtrate care being taken to avoid coloring the filtrate too strongly with this indicator.
6. Titrate the acidified filtrate for residual silver nitrate with 0.01 N solution of ammonium thiocyanate from a microburette until the reddish color of the ferric salt persists.
7. The amount of acetylene present can be calculated from the equation given by Nifontova (1939) $2\ AgNO_3 + C_2H_2 + 2NH_4OH = Ag_2C_2 + 2NH_4NO_3 + 2H_2O$.
8. If interfering substances are present in the water, the acetylene can be distilled slowly from a measured quantity of sample into a tall slender tube containing the ammoniated silver nitrate solution.

REAGENTS

0.01 N silver nitrate solution. — Dissolve 1.7 grams of silver nitrate in distilled water and dilute to 1 liter.

Concentrated ammonium hydroxide. — A 28 percent solution, NH_3.

Strong nitric acid. — A 69 percent solution, HNO_3.

Ferric ammonium alum indicator. — Dissolve 70 grams of ferric ammonium sulfate crystals in 200 ml. of hot water. When cool, filter and make up to a volume of 250 ml. with dilute (6 N) nitric acid (Hodgman and Holmes, 1941). For the 6 N nitric acid, dilute 55 ml. of 69 percent HNO_3 to 100 ml. with distilled water.

0.01 N ammonium thiocyanate (NH_4SCN). — Dissolve 7.612 grams of ammonium thiocyanate with distilled water, adjust to 100 ml., redilute by bringing 10 ml. of this to 1 liter.

SPECIAL DETERMINATIONS

In addition to the determination of the substances which have been presented as probable components of polluted waters, analyses for other elements or compounds must be made from time to time in the studies of specific cases of pollution. It is not possible to predict all of these substances so the investigator will be obliged to consult the various texts on analytical chemistry, and often will be forced to devise his own procedure to meet particular conditions.

Among these analyses which are not routine, some are used more frequently than others. A few of these for which the writers have found certain methods successful are listed to give the reader opportunity to locate a method quickly for these substances although it does not seem desirable to give these procedures in detail here.

ARSENIC

The authors (Ellis, Westfall, and Ellis, 1941, a and b) in an extensive series of analyses of waters, muds, and tissues of fishes exposed to various arsenicals found the mercuric chloride method of Cassil and Wichmann (1939) for the determination of small amounts of arsenic very accurate and dependable.

ALUMINUM

The increasing use of aluminum in industry has directed attention to this element in several effluents. The hematoxylin lake method of Hatfield (1924) and the two-color method as discussed by Knudson, Meloche, and Juday (1940) have been adapted for laboratory studies of aluminum in water by the authors.

CYANIDES

Modifications of the copper-acetate-benzidine procedure of Moir (1910) have been used in some tests and quite accurate results have been obtained with distillation method of Childs and Ball (1935).

LEAD

The dithizone method (Clifford and Wichmann, 1936) is the most satisfactory for small quantities of this element.

PHENOLS, CRESOLS AND RELATED COMPOUNDS

These compounds are very difficult to determine accurately and with certainty although this group of substances is involved in many cases of stream pollution.

The range of toxicity of the phenolic substances (Gersdorff, 1937 a and b) varies with the purity of the substance, the presence of closely related compounds, with the acidity of the water and the amount of dissolved oxygen, but, in general, damaging or lethal effects can be expected if 10 p. p. m. or more are present, although sometimes much larger quantities are tolerated by fishes. However, in addition to the lethal effects, non-lethal amounts often are taken up by the living fish and the flavor of the flesh seriously impaired. Goodnight (1942) found 0.2 to 0.6 p. p. m. of sodium pentachlorophenate and pentachlorophenol lethal for fresh-water fishes.

The authors have found a modification of the method described by Pearl and Benson (1940) for the detection of sulfite paper mill effluent helpful in tracing phenolic and related compounds in stream waters. A 10 percent solution of sodium nitrite followed by 10 percent acetic acid, and after the color develops, with 50 percent ammonium hydroxide will bring out a good color in water samples carrying very small amounts of phenols, cresols, and many paper-mill wastes, but the test is complicated by the fact that tannic acid, pyrogallic acid, salicylic acid, and sulphanilic acid also give colors with this reagent. However, by elimination the test can be used as a tracer locally.

The method of Deichmann and Schafer (1942) has been adapted to the determination of small amounts of phenol in fish tissues and to water samples.

SELENIUM

The toxicity of small amounts of selenium to fishes has been demonstrated by Ellis, Motley, Jones, and Ellis (1937), and as this element occurs in the soils of several western States and in the smoke from smelters, analyses for small quantities of this element are called for occasionally.

The thiourea method of Falciola (1927 a and b) has been modified for semiquantitative tests for selenium and tellurium, but for accurate analyses involving small amounts of selenium, the distillation method of Robinson, Dudley, Williams, and Byers (1934) and the microtitration method of Wernimont and Hopkinson (1940) are recommended.

EXPLORATORY TESTS

As the detailed procedures for quantitative analyses are usually time-consuming and often require elaborate laboratory facilities, short qualitative to semi-quantitative tests are often very helpful in the field in establishing the presence or absence of many elements and compounds in a stream. These brief procedures are particularly valuable in planning further detailed study and minimizing the amount of water to be collected and shipped to the laboratory for further analyses. However, the use of these tests must be limited to orientation, and must not be substituted for the detailed quantitative procedures required in a complete survey.

The tests which follow have proved useful in a variety of field operations and the authors recommend that separate kits containing the reagents required for the particular tests which seem pertinent to the problem in hand be carried in the field. It is not always necessary to take a full complement of reagents covering all of the tests suggested, as often the observer realizes in advance of the actual field work that only certain substances are involved. On the other hand, water-quality problems are complicated and these exploratory tests may reveal some unexpected compound as the significant substance. As in all field work, the observer's ingenuity is constantly taxed, and the exploratory tests will help materially in the evaluation of possible leads and explanations. These tests are based on well-known chemical reactions adapted to water-sample studies.

CHLORIDES

To a 5 ml. sample in a test tube, add two drops of a 2 percent solution of silver nitrate in 1 to 3 nitric acid solution. A white precipitate indicates chlorides. Add two drops of concentrated ammonium hydroxide. If chlorides are present, the solution will clear. If thiocyanate or cyanide is present, a white precipitate is formed, thus invalidating the test for chlorides in the presence of these compounds. However, thiocyanates and cyanides are seldom found in waters except in wastes from a few industries, such as electroplating, and the gold cyanide extraction process. This test is positive for chlorides in a concentration of three or more parts per million. The treated sample should be checked for a precipitate immediately on the addition of the silver nitrate, especially if in bright sunlight, as the light will free some colloidal silver resulting in a purplish blue color.

SULFATES

To a 5 ml. sample in a test tube, add 0.5 ml. of benzidine solution and allow it to stand for a few minutes. A precipitate indicates sulfates. This test is positive and practical in concentrations of two parts or more of sulfates per million.

PHOSPHATES

To a 5 ml. sample in a test tube, add 0.5 ml. of ammonium molybdate solution and one drop of one percent stannous chloride in 1 to 5 hydrochloric acid solution. A blue color develops in the presence of phosphates in a concentration of 0.05 part or more per million. Silicates in large quantities or arsenates of 0.1 p. p. m. will interfere by forming a blue color.

SULFIDES

To a 5 ml. sample. add 1 drop of concentrated ammonium hydroxide solution and 5 drops of 10 percent sodium nitroferricyanide. A violet color will develop in the presence of sulfides.

CHLORINE

To a 5 ml. sample in a test tube, add 2 drops of potassium iodide solution, and 2 drops of starch solution. A blue color indicates chlorine. Manganic manganese, ferric iron, and nitrites interfere in solutions more acid than pH 4.2 If the temperature of the sample during the analysis is kept below 20° C., 0.1 p. p. m. chlorine can be detected.

IRON

To a 5 ml. sample, add 2 drops of 0.6 percent potassium permanganate, 2 drops of concentrated hydrochloric acid and 0.5 ml. of 60 percent potassium thiocyanate. A pink or red color indicates iron. This method is sensitive to 0.1 p. p. m. total iron.

FLUORESCENCE

Ultraviolet light, particularly the ultraviolet light near 3650 A.U., known as long wave length ultraviolet, is a valuable aid in tracing and identifying some effluents and polluted waters and also in disclosing the storage of certain elements as zinc, in various parts of aquatic organisms. Some unpolluted natural waters fluoresce as would be expected because traces of many elements and compounds respond to light of various wave lengths in the ultraviolet series. Therefore, before attempting to trace or evaluate a pollutant by means of fluorescence, the action of the unpolluted waters must be ascertained. However, even though the unpolluted waters have a natural fluorescence, it may not be of the same color or shade as that of the polluting substances so that the fluorescence of unpolluted water itself, if there is any, usually does not alter the value of the flourescence test for certain effluents. On the other hand, many substances do not fluoresce so numerous effluents and pollutants are not responsive to ultraviolet light.

In field operations, the following sequence has been adopted and if fluorescence is found, its usefulness in the particular problem can soon be established.

First, the unpolluted water is tested with ultraviolet light and the color, relative intensity, and after-glow noted. Then the full-strength effluent is examined in ultraviolet light and its responses noted. If the effluent fluoresces sufficiently, a series of volumetric dilutions is prepared at once, using the unpolluted stream water from a source upstream and as close to the point of entry of the effluent as possible, as the diluent. When this series is viewed in ultraviolet light, the limit of dilution at which the fluorescence is still strong enough to be serviceable is established.

Subsequently, samples taken at various stations downstream are examined and the spread of the pollutant followed. However, many substances extinguish fluorescence and others excite fluorescing material, therefore, in tracing a fluorescent effluent down the stream, water from side streams should also be used in dilution tests with the effluent to ascertain whether they extinguish or enhance the fluorescence of that effluent. Often surprising results are obtained in tracing a fluorescent effluent and attention may be directed to other unsuspected pollution.

The number of fluorescent substances is very large and for specific lists, the reader is referred to the various books on fluorescence but the identification of the specific substance causing the effluent to fluoresce is often of little importance for the fluorescent marker in the effluent may be an unknown compound. In using this specific test to follow effluent dilution downstream, the statement made under discussion of effluents must be repeated, namely, effluents are composites and the presence or absence of any component does not mark the presence or absence of the entire effluent, for the several substances comprising the effluent have different rates of oxidation and other properties so that they disappear in the stream at different rates. The fluorescence marker, therefore, enables one to trace the course of the water which is polluted by the effluent downstream and marks the persistence of the specific fluorescent substance.

The response of many effluents to ultraviolet light is very marked and fluorescence has been particularly effective in tracing certain oils, petroleum derivatives, wood pulp extractives, cellulose wastes, organic nitrogen compounds, and some minerals. However, wastes vary and the particular effluent under consideration must be evaluated individually and its fluorescence noted specifically.

Effluents containing certain fluorescent material, as zinc compounds, may produce fluorescent deposits on aquatic animals which have been exposed to the particular waste. Examinations and autopsies of such fishes and other aquatic animals, when made under ultraviolet light, may reveal storage or precipitation of some components of the effluents in particular parts of the body. Gills of fishes on which the zinc-organic complex has begun to form as a result of the exposure to soluble zinc salts are an example of this type of material.

Normal animals may also store certain fluorescent materials. Brooks (1936) found that the skin of frogs fluoresces because of the presence of zinc and the writers have made similar observation on certain cyprinid fishes.

In the laboratory, powerful sources of ultraviolet light and various screens are available for use in studies of fluorescence. For rapid field work an argon-filled bulb, which operates on standard electric light circuits, housed in a small black box which is provided with a series of Corning ultraviolet transmitting glasses to fit an opening in front of the target of the light, has given very satisfactory results for exploratory and tracing operations.

The water samples are studied in fused quartz containers and should be examined as soon as possible after collecting if the fluorescent material is organic. Mineral salts, particles of silt, and rock powder are less perishable although some of these are subject to a certain amount of oxidation.

Ultraviolet light equipment can be obtained from various standard supply houses.

EFFLUENTS AND TRADE WASTES

Despite the fact that various so-called tests have been proposed for particular trade wastes and other pollutants, actually no "tests" for the presence or absence of a trade waste or effluent as such exist, as these determinations merely point out certain specific components of the wastes and cannot be applied to the effluent as a whole. It is not scientifically sound, therefore, to state that a given effluent was found in a particular part of the stream in a concentration of 1:1000 dilution just because one of these "tests" showed the presence of one of the components of that waste to be present at that particular point in a concentration of 1:1000. The many components of these complicated trade wastes may oxidize at different rates, may or may not combine with various constituents of the stream water, may or may not be destroyed by other substances in the water, by sunlight, or by wave action, so that the dilution and disintegration of the effluent does not proceed as a unit as it would were there but a single substance present.

The toxic or detrimental actions of a given waste may result from one or more substances in that waste and these substances may or may not be the compounds for which chemical or other tests are known. It does not follow that because one of the innocuous components of a waste is found in a given concentration at a given point in the stream that the substances detrimental to fish life which are also components of this waste are present at that particular point in the same concentrations, for the detrimental substances may have quite different breakdown reactions from those of the substance used as the indicator in the test. It is possible, therefore, to report the absence of a particular waste on the basis of a test which covers only one constituent, and still find by bioassay or other procedure that the toxic complexes are present even though the innocuous one may have been destroyed, or vice versa.

Various effluents are more dangerous to aquatic life after having been in the water for a time than they are when first introduced into the stream, because new products are formed by oxidation, bacterial action or combination with other substances in the stream water, and although the original effluent is no longer present as such, a new pollution hazard has developed which, of course, would not have been produced unless the original effluent were placed in the stream.

It is absolutely essential, therefore, in the studies of biological hazards of any effluent to isolate, if at all possible, the several components responsible for the detrimental effects on fishes and test for these specifically. It is not always possible to make complete separations but a system of fractionation is at least helpful.

In determining the effects of any effluent, the following sequence of procedures will point out the major hazards of the pollutant and indicate the fraction or fractions to be given detailed chemical and bioassay studies.

HYDROGEN-ION CONCENTRATION ACTION

Many effluents are dangerous because of high acidity or high alkalinity and until that factor is accounted for, other detrimental actions may be obscured. If the effluent (p. 42) has an initial pH more acidic than pH 6.0 or more alkaline than pH 8.7, the following dilution tests should be made at the stream side.

The full-strength effluent should be carefully diluted usually in a logarithmic series, i.e. 1:10; 1:100; 1:1000, continuing as far as is desirable, with stream water taken above the point of entry of the effluent but as close to that point as feasible. These resultant dilutions with stream water should be tested at once and the pH determined. The dilution must be continued until a pH value lying between pH 6.5 and pH 8.4 is found; i.e., until a dilution is located which has reduced the pH of the effluent to a hydrogen-ion level harmless to fishes. After this dilution has been found, a more accurate dilution limit should be determined by interpolating other values between the strongest concentration which is out of bounds and the lowest concentration which is just within bounds. In this way the critical dilution point for the removal of the pH hazard of the effluent by the stream itself can be determined quite exactly.

To aid in the evaluation of the dilution curve, the total acidity or total alkalinity of the undiluted effluent and of the effluent in the dilution at which the pH has been brought to a level not hazardous to fishes, should be obtained by direct titration (q.v.). From these total acidity or total alkalinity values, the severity of the pH hazard of the particular effluent can be evaluated readily. The dilution curve should be plotted so that the hazard at any given dilution can be read from the chart.

SPECIFIC CONDUCTANCE VALUES

Some effluents are dangerous to aquatic life because of the load of dissolved ionizable material carried by them, even though these ionizable substances are not dangerously toxic in themselves. Other effluents, although carrying smaller quantities of salts or acids may have sufficient quantities of these to affect the buffer system of the water. The same dilutions, i.e., those prepared from the full strength effluent and stream water for the pH curve, can be used in constructing this conductance curve. The specific conductance of the stream water above the point of entrance of the effluent and the conductance of the full-strength effluent should be the two ends of this dilution curve. The limits of specific conductance tolerated by fish life are discussed under the section Specific Conductance (q.v.).

OXYGEN DEMAND

Various effluents contain sulfites, thiosulfates, polythionates, and ferrous iron compounds (p. 16) which not only reduce the Winkler reagents but also take up dissolved oxygen from the water in the course of various chemical changes. In addition many organic compounds present in certain types of effluents, such as paper mill wastes, sewage, cannery wastes, and sugar refinery wastes have high oxygen demands which in many cases are enhanced by bacterial action.

As these different substances, both organic and inorganic, are chemically different and, therefore, are capable of many different reactions, their oxygen demands, the sequence of products formed during oxidation and even the speed of oxidation vary greatly. Hence, it is not possible unless the exact nature and quantity of each substance is known (a task which in the case of most effluents is a huge chemical undertaking) to compute exactly the oxygen demand of any given effluent. Various relative or indicator methods have been suggested for the determination of these active, latent, or potential oxygen demands.

All are more or less unsatisfactory but the method which gives the best results for a generalized interpretation of the greatest oxygen demand of any given effluent is the potassium permanganate method (q.v.).

The oxygen consumed by permanganate should be determined for the full strength effluent and for several expected dilutions. From these values, only estimations can be made concerning the dissolved oxygen which the effluent may be expected to remove from the stream. If the amount of oxygen consumed exceeds the available dissolved oxygen carried by the stream (when corrected for volume of effluent and volume of stream flow) a dissolved oxygen crisis can be expected, particularly in warm weather. The dissolved oxygen hazard of the effluent should always be determined.

BIOASSAYS

Various dilutions compounded from unpolluted water and the full-strength effluent should be subjected to bioassay tests as soon as possible after the effluent is collected. Many effluents contain volatile substances which may be lost if the effluent is not tested at once. Various components of the effluent may oxidize, change, or even precipitate out on standing so that tests with old effluents are often not strictly comparable to those made with fresh effluents.

The bioassays should cover the dilutions which were determined in the pH and conductance studies and, in addition, in the first test, a logarithmic series of dilutions starting at 1:10 or 1:100 and carried out to as weak a dilution as may be necessary to determine the minimal lethal dose (m. l. d), that is, the quantity of the effluent which will kill the test animal (p. 101.) within 48 hours when diluted with average unpolluted water comparable to the water into which the effluent is being poured. This test water must be free from any unusual elements, must not be strongly chlorinated, and should contain small quantities of carbonates. In other words, it should be a water suitable for fish life and proven by actual experiment to be acceptable to the test fishes. The exact composition of the diluent water should be stated. Under no circumstances should distilled water be used in these bioassay tests as many samples of distilled water are in themselves detrimental to aquatic life.

From these bioassay tests, the approximate m.l.d. can be obtained and the reactions of the dying and moribund fishes noted. The physiological reactions of the fishes succumbing to the effects of an effluent are highly important as they often give valuable clues to the nature of the toxic substances involved. For example, if the fish when first affected by the effluent become extremely sensitive to vibration, compounds having an effect on the central nervous system as phenols, cresols, picrotoxin, DDT or "fish berries" are suggested. Gasping movements and continued swimming at the surface point to substances interfering with respiration, as acids and heavy metals which coagulate the mucus of the gill filaments, or to low dissolved oxygen.

No set rules can be given but as the experience of the observer increases, the value of these phyiological reactions becomes more evident.

Having determined the m.l.d. in these preliminary tests, long-time experiments covering survivals for at least ten days should be run (p. 104). If the effluent was found to be strongly acidic or strongly alkaline, the undiluted effluent should be carefully neutralized using either sodium hydroxide or hydrochloric acid and an external indicator, and bioassay tests covering the same dilutions of the neutralized effluent as those found to be hazardous when the unneutralized effluent was used, carried through until an m.l.d. is established for the neutralized effluent. In this way the synergistic action of pH can be determined. This is often a very important factor for it has been shown that fishes succumb to various poisons and to low oxygen in water having an acidity greater than that to which the fishes are normally exposed, more rapidly than when the pH is held within the usually expected ranges (Westfall, 1945; Jones and Ellis, 1945).

FRACTIONATION OF EFFLUENTS

After having eliminated or compensated for the effects of pH, strong concentration of ionizable material and oxygen demand, and after having determined the approximate m.l.d. of the effluent, efforts should be made to isolate the detrimental fraction or fractions for identification.

Several methods are useful and are given below, but new effluents often present new problems and the scientific skill and knowledge of the investigator must be used, that is, the procedures outlined although helpful in most cases may not suffice for the isolation of the dangerous portions of certain effluents.

DIALYSIS

The separation of dialyzable substances from non-dialyzable materials by the use of membrane is a well-established procedure in both investigational and commercial operations. The authors have found the tubular cellophane which can be obtained from various chemical supply houses in long rolls excellent for this work. A piece from 9 to 12 inches long is moistened at one end and carefully sealed by turning in and tying securely the free edge with a soft string. Care must be used to avoid cutting the cellophane with fine thread but the operator must be equally sure that the tube is securely and completely tied shut.

The sack is then filled with distilled water and hung by means of string or wooden clamp attached to the top (no metal) in a tall jar of tap water for half an hour or so. The sack is then ready for use. It is lifted carefully from the jar and emptied of all fluid. The sack is then filled to within approximately 3 inches of the top with the effluent to be fractionated. The quantity of effluent placed in the tube must be measured exactly and at least 3 inches of unfilled tube at the top should be allowed for changes in volume of the effluent should it contain non-dialyzable material which will increase the volume by imbibition of water during the process of dialysis.

The properly filled cellophane sack is suspended free (care must be taken to avoid touching either the sides of the jar or any object in the jar) in a tall glass jar of either tap water or distilled water. The effluent level inside the cellophane tube should be approximately in line with the overflow level of the glass jar. A glass tube is also placed in this jar so that one end of this glass tube rests on the bottom of the glass jar and the other projects above the top of the jar. Through this tube a continous flow of either tap water or distilled water must be maintained during the period of dialysis which must be continued for at least 12 hours. The overflow water leaving the top of the glass jar is not collected or saved in this particular form of separation.

For practical reasons, tap water (not heavily chlorinated) is usually satisfactory for the first sets of dialysis if it has been shown that this tap water is acceptable to fishes; that is, the tap water must contain no substances which might contaminate the effluent sample. The small quantities of sodium and magnesium salts and of chlorides, sulfates, and carbonates usually found in tap water can be disregarded in most of these dialysis separations. However, if the results warrant, distilled water can be used for very exact separations.

As the quantity of the effluent placed in the sack was carefully measured, the total volume of the residuum remaining in the tube after 12 to 24 hours dialysis must be measured and aliquot parts taken for the subsequent bioassays. In this way, equivalent volumes of the effluent can be computed.

In the procedure just described the dialysate is lost so that bioassays of the residuum must be compared with bioassays of the whole effluent. If the residuum is less toxic than the whole effluent or without toxic effects at all, the dialysate is indicated as carrying some or all of the toxic components. If the residuum is essentially equal to the whole effluent (when proportional parts are taken) in toxic effect, then the dialysate is apparently nontoxic. Sometimes, toxic principles are to be found in both the dialysate and the residuum. However, the procedure outlined should be carried through first and tests made with the residuum.

If toxic principles are indicated in the dialysate, a new preparation must be used and instead of standing the dialyzing sack in flowing water, the sack filled with fresh full-strength effluent is immersed in as small a volume of water as will cover the entire sack to the level of the contained effluent. This water outside the sack is poured off and saved every two hours, and is replaced by fresh water of the same composition as that used in the first case. The combined dialysate waters are measured and aliquot portions incorporated in either the bioassay tests, or are concentrated as desired.

FRACTIONATION BY FREEZING

The concentration or fractionation of mixtures by freezing out a portion of the water is an effective means of studying the composition of certain effluents. For this purpose, the authors have packed pyrex flasks carrying about two-thirds of their capacity of the effluent, in dry ice, and by rotating the flask continuously have often been able to separate out greatly concentrated fractions in the central unfrozen well; water and substances of low freezing point forming an ice shell lining the flask. Quick decantation of the fluid from the central well and subsequent melting of the frozen material from the flask provide a very effective method for the separation of various components of numerous efflluents. Many volatile compounds in wastes as, for example, waters from oil fields which would have been driven off by evaporation are readily concentrated in the unfrozen portion within the ice well.

FRACTIONATION BY EVAPORATION AND DISTILLATION

Evaporation or distillation under reduced pressure or with heat provides means for concentration or fractionation of some types of effluent. Heat, however, should be used with great caution as many effluents are changed by the application of heat.

FRACTIONATION WITH NON-MISCIBLE SOLVENTS

The use of the separatory funnel procedure is often very helpful in separating fractions of effluents for both biossays and chemical determination.

A known quantity (250 ml. is a good workable unit) of the untreated effluent is put into a large separatory funnel having a glass-stopper at the top and glass stopcock at the bottom, and shaken well with a known quantity of one of the solvents listed below. The separatory funnel is then placed in a rack and sufficient time given for a complete separation. Sometimes a few minutes will suffice; again, several hours may be required.

When the separation is complete, the several layers can be drawn off individually and measured. The volatile solvent is then eliminated either by direct evaporation or under reduced pressure if the nature of the fraction permits, and the residue is ready for bioassay tests. It is, of course, absolutely essential that the solvent be removed before making the bioassays.

The solvents which the writers have used routinely in these separations are chloroform, carbon tetrachloride, carbon disulfide, and amyl alcohol. Ether can be used in some cases but because of its greater miscibility with water, an intermediate layer which carries a mixture of fractions is usually formed.

FRACTIONATION BY PRECIPITATION AND FLOCCULATION

These procedures border on the chemical separations, but three, at least, have proven helpful in general work with effluents.

Alcoholic Precipitation

Place a small sample, not over 20 ml., of the effluent in a tall glass-stoppered graduated 100 ml. cylinder and add a few ml. of 95 percent ethyl alcohol. Stopper, upend the cylinder for mixing, and set aside for a few minutes. If the alcohol has produced a separation of effluent components, the amount of alcohol used should be recorded. Repeat this procedure, adding more alcohol. After several additions of alcohol, the fractionations if any and the volumes of alcohol required to produce them will have been determined. Using these values suitable mixtures of alcohol and effluent can be prepared to yield sufficient quantities of the fractions for bioassays. Before either the filtrate or residue from any of these separations are used for bioassay, the alcohol must be removed by evaporation or under reduced pressure.

Acetone Precipitation

Proceed as directed for alcoholic precipitation.

Flocculation with Aluminum Hydroxide

Using the same procedure described under clarification, q.v., effluents can often be fractionated by aluminum hydroxide flocculation. If the floc is used for bioassays, due allowance must be made for the small amount of aluminum which has been added.

Chemical Fractionation

After the general separations indicated in the preceding paragraphs have been made and the toxic fraction or fractions located, chemical analyses are often advisable. The analyses must be made according to the recognized analytical procedures and can be carried to any desired extent depending upon the importance of the work.

EVALUATION OF POLLUTION HAZARDS

The specific toxic and detrimental actions of pollutants on aquatic life are readily determined by bioassays, but owing to the limitations of experimental tests the chronic and long-time effects should be ascertained by surveys of the polluted areas. Both methods are useful, but neither can be used alone if complete and valid evaluations of pollution hazards are to be made. All too often the supposedly simple test of placing a crate of living fish in the polluted stream and noting survival or death of the caged subjects has been offered as conclusive proof of the presence or absence of dangerous pollution. In general, such tests are both unscientific and unreliable for the survival of fishes even for several days in any given water does not prove the absence of pollution, nor does the sudden death of the test fish prove the contrary.

It is well established that the physiological effects of many substances on living animals vary with many factors which in turn may also be variable. It is only possible to define the toxicity of a particular material when the factors which contribute to the total reaction are controlled, and even then the minimal lethal dose as determined under specific conditions cannot be expected to be valid for other combinations of conditions. It is, therefore, the scientific obligation of the aquatic biologist who essays to evaluate a pollution complex to duplicate the essential features of that particular complex as far as possible in his experimental tests and to state concisely the conditions contributing to his findings. In dealing with a specific effluent and pollution problem, it is not safe to assume that previous findings on a similar effluent in some other stream can be applied directly to the present situation without first testing the particular effluent involved and obtaining data on conditions in and the biota of the stream under consideration, to ascertain how far such a carry-over of these previous findings is warranted.

Minimal lethal doses of pure substances are very difficult to define as every pharmacologist and toxicologist well knows, so that at best the minimal lethal dose is a quantity which may be expected to kill most of the animals of a given species under average conditions. However, age, sex, condition of nutrition, physiological state, tolerance either natural or acquired, and many other biological characteristics of the individual, as well as various environmental factors, all modify the lethality of specific substances so greatly that double the m.l.d. may not seriously affect one individual under certain conditions although one-half the m.l.d. may kill another.

However, trade wastes, industrial effluents and even sewage are not simple solutions or suspensions of a single substance but are complex and often variable mixtures of many substances some of which are innocuous; some are dangerous in combinations or after modification in the stream, and others are specifically toxic to living organisms. The assay of the effluent for substances dangerous or toxic to aquatic life is complicated at once, therefore, by the factors of physiological synergy and antagonism between the various components of the effluent.

A minimal lethal dose with even the limitations of that value as described for a single pure substance cannot be designated for any of these complex trade wastes. The m. l. d. must be given for specific components alone, and the waste from a particular plant must be evaluated as such. Consideration must also be given to the ranges of variation of the several components to be expected in that effluent. It would seem that an established process making a predetermined set of products should have a fairly constant type of effluent. This, however, is very rarely the case. Among the factors responsible for the variations in composition of effluent from specific plants or industries are the variations in the raw materials used, the variations in the sequence of dumping different vats or units in the several parts of the process and the dilutions from wash waters, waste steam, and plant sewage. Many other variables enter into plant operations so that the aquatic biologist must be sure that adequate samples of the effluents are taken at intervals great enough to insure material from which the ranges of expected variations of the hazardous components of the effluent can be determined.

Pooled samples must never be used, that is, samples made up of lesser samples collected at intervals over any given period of time. Often these composites are of value to the plant officials or other interests, but the aquatic biologist must determine the extremes of concentration of the dangerous components which extremes are usually wiped out by the averaging effects in pooled samples. For example, if the acidity of a given effluent rises to pH 4.0 at any time and a slug of this type be poured into the stream for only a few minutes, a serious condition could be produced and fish killed for long distances below the point of entrance of the effluent, although due to the neutralizing effects of other components of this effluent which may be released in larger quantities at other intervals, a pooled sample from this particular plant might have shown an alkalinity of pH 8.0. That is, the effluent would have been slightly alkaline and as far as the effects of hydrogen-ion concentration are concerned would have been harmless to most aquatic life. Evidence of such irregularities in the composition of the effluents discharged is often apparent from the survey of the stream in the zone below the entrance of the particular waste. If this zone for some distance downstream is devoid of aquatic life or has greatly reduced fauna and flora, even though the effluent in general seems innocuous, suspicion is at once directed to slugs of highly toxic effluent, or to the presence of smaller quantities of substances producing chronic conditions which ultimately destroy the aquatic biota.

BIOASSAYS

Bioassays supply definite information on the general toxicity of the effluent, on the nature of the toxic action if any, and on the expected dilution or other corrective procedures required to reduce the toxic or detrimental effects to a non-hazardous level. In general, bioassays on aquatic animals are conducted by exposing the test animal to known concentrations of the effluent in suitable waters of known composition and of proven acceptability to the test animals.

WATER

Distilled water is very rarely used in bioassays because of the detrimental actions of distilled water on many aquatic organisms. It might seem at first that the use of water from the stream into which the effluent is being poured would be indicated in the bioassays. Although the stream water itself is essential in certain dilution studies (p. 94), the use of the stream water for the determination of the general toxicity of the effluent and its various fractions is not as advantageous as might be believed. Often the stream water already has pollutants or other substances in it which will affect the action of the effluent under consideration so that spurious results concerning the actual toxicity would be obtained. In the basic and orientation bioassays, it is always desirable, therefore, to use a relatively pure natural water containing small quantities of sodium, calcium, magnesium, carbonates, sulfates, and chlorides usually found in natural fresh waters. If the pollution problem involves brackish or salt waters, suitable brackish or salt waters must be used in at least some of the bioassays. Natural pond, lake, and river water, if free from polluting substances, or good potable tap water, if it does not contain excess chlorine introduced for sterilization or bacteriostatic action, are usually quite satisfactory for general bioassay tests, if as noted before, it has been proven in advance that the test animal will live successfully in the water chosen. It is always important that an adequate supply of the water be available as running water, that is, water collected in carboys and held even for a few days becomes unsafe for experimental tests.

Water to qualify for bioassay work should have a specific conductance between 100 and 800 mho × 10^{-6} at 25° C., a pH between 7.2 and 8.4, dissolved oxygen not less than 4 p.p.m. should be colorless and free from suspended matter and should not contain any unusual quantities of the trace elements which are found in normal natural waters nor any quantity of any substances known to have cumulative detrimental action on aquatic life. A complete chemical analysis of the water should be made and a spectroscopic analysis obtained if possible.

TEST ANIMALS

As various species of fishes differ in susceptibility to many toxic agents or combinations of damaging conditions, it is not possible to choose a single species of fish to serve as a universal test animal where aquatic complexes are concerned. Ideally, the species of fishes in the particular stream where the pollution is to be evaluated should be used as test animals but this is not always practicable. There are also valid physiological reasons against using certain species of fishes as test animals, for many fight captivity and remain in a highly excitable state when under experimental conditions, refusing to eat and otherwise becoming unreliable biological reagents. It is, therefore, necessary to choose fishes of the species which not only tolerate captivity readily but which can be maintained under restricted experimental conditions with reasonable care.

The common goldfish, *Carassius auratus,* meets these specifications and has been used extensively as a test animal in many types of bioassays. As the goldfish is available through commercial hatcheries, can be held in excellent condition for weeks in concrete tanks, and can be fed easily in individual experiments, this species has much to recommend it as an aquatic test animal. Comparative tests have shown that the goldfish is on the whole more resistant to pollutants and to unfavorable water conditions than some of the game fishes. This is to be expected as the goldfish belongs to the carp group of cyprinids. This hardiness of the carp is advantageous in general bioassay work, in that conditions or concentrations found to be unfavorable, harmful, or lethal to goldfish will almost certainly be detrimental to any of the fresh-water game and food fishes.

The authors have also used the top-minnow, *Gambusia patruelis,* extensively as a test fish. The top-minnow adapts itself readily to laboratory conditions and because of its small size can be used for experiments where space must be conserved. The catfish or fiddler, *Ictalurus punctatus,* is an excellent test fish, particularly for experimental work where chronic poisoning is to be followed over a period of several weeks. The orange-spotted sunfish, *Lepomis humilis*, the small-mouth black bass, *Micropterus dolomieu,* the common perch, *Perca flavescens,* and the gizzard shad, *Dorosoma cepedianum*, have also proven good test fish for particular types of assays where warm-water fishes were desired. The salmonids, that is trout and salmon, are excellent test fishes as representatives of the cold-water series if the proper environment, including cold, running, well-aerated water, be maintained. Consequently, special hatchery equipment is usually required where these species of fishes are to be tested. The United States Fish and Wildlife Service maintains such a hatchery test station at Spearfish (S. D.) and the authors have used rainbow trout, Loch Leven trout, brook trout, and Pacific salmon with success in bioassays series.

It is often important to learn the effects of effluents on various organisms which enter into the several food chains of the fishes under consideration. Diatoms, protozoans, daphnia, gammarids, crayfish, and mayfly larvae have been used frequently in our laboratories as biological reagents. Again there are often wide differences in the tolerance of the various organisms for specific substances and as the bioassay is essentially an exploratory test for toxicity, the exterminating action, if any, of the effluent on these forms is best learned from the survey studies of the stream unless it be desirable to acertain the specific action of the effluent on a particular form.

Of the invertebrates listed above, the authors have found daphnia, *Daphnia magna*, the most easily handled and the most practical test form. Daphnia can be raised readily in culture jars and the chronic effects as seen in the action on reproduction and life span as well as the specific toxicity followed quite accurately with this crustacean. As has been noted by various students of daphnia, these animals are often susceptible to slight changes in the composition of surrounding water, which changes may occur quite independently of any added toxic substance or effluent. These unexpected changes sometimes make it necessary to discard extensive series of daphnia after they have been followed for some time. However, these animals if raised carefully provide an abundant source of rather uniform test material which is very valuable for some phases of the bioassay work.

BIOASSAY PROCEDURES

Fixed Volume Tests

Bioassays of this type, supply data rapidly and easily on the acute lethal action, the lethal quantity, and the detrimental range of the whole effluent, and on the acute minimal lethal dose and detrimental range of specific substances or separate components of effluents. As the terms acute and long-time are relative and must be defined, the authors have chosen 24 hours to mark the end of the first acute period, 5 days the second acute period, and 10 days the third acute period, as survivals of less than 24 hours, between 24 hours and 5 days, and between 5 and 10 days give significant groupings concerning the relative toxicity of the substance under test.

Obviously, the time limits designated are somewhat arbitrary except as they have been shown to be useful over a period of years during which thousands of bioassays have been conducted. Regardless of the terminology, the survival time must be reported as exactly as possible in all cases, as often the survival time is one of the most important items in the evaluation.

Glass battery jars of the type used in rural storage battery lighting plants are very satisfactory individual units for this type of bioassay. Four liters of the test solution made by adding the required amount of the effluent or test substance to a known quantity of the diluent water (characteristics of which have been discussed previously) so that an exact dilution is known, are placed in a clean dry battery jar and one test fish placed in each jar. It is advisable to make up a little more than the total amount of diluted effluent required for each group of jars in a large carboy so that there will be some of the solution available for the determination of pH, conductivity and other characteristics at the start of the test. During the test, the 4-liter volume in each jar must be maintained. Goldfish under 4 inches over-all length and top-minnows are especially good for this type of assay as they are not disturbed by confinement in the glass jar and if the dissolved oxygen in the 4 liters of fluid should be reduced by the test substances, these fishes can survive for a time by coming to the surface of the water for air.

As it is often necessary to differentiate between the truly toxic effects of the substance and its oxygen demand which may reduce the dissolved oxygen to a critical level, two series of fixed volume assays are usually run in parallel, one without aeration and the other in which each jar of the series is supplied with a glass tube from which filtered and moistened air bubbles up through the solution providing continuous aeration. Continuous aeration is not feasible, however, for tests on some effluents, as these may be oxidized or their volatile components be driven off during the aeration.

In both types of fixed volume assays, that is the non-aerated and aerated, two sorts of controls must be maintained. At least one jar of the test solution in each series must be carried without a fish so that the physical and chemical changes in the undisturbed solution due to ageing, oxidation, or other factors can be followed during the bioassay test. In each series, several jars of plain water, each carrying its single test fish, must be maintained to prove that the survival of test fishes under the existing experimental conditions but without the detrimental action, if any, of the effluent, could be expected.

At the start of the experiment, the temperature, pH, specific conductance and dissolved oxygen of both the control and test jars must be recorded. Temperature is usually regulated in bioassay work by almost submerging the jars in tanks through which water flows continuously in sufficient volume to maintain a constant temperature of ±2° C. A recording thermograph should be maintained in some part of the cooling system so that any deviation in temperature control can be noted. For warm-water fishes, 20° C. is a very acceptable temperature for bioassay work, but either higher or lower temperatures may be desirable if the action of the effluent under particular conditions is required. The temperature at which the test is carried must be left, therefore, to the operator, but it must be uniform and must be recorded as an essential part of the data. If only one goldfish under 4 inches, over-all length, or one top-minnow is used per jar containing 4 liters of test solution, the solution should be changed every 24 hours. The new solution should be prepared and brought to the same temperature as the old solution in a new series of clean jars filled and labeled. The individual fishes, each of which should have a serial number, are quickly transferred to the properly numbered jars of fresh solution using a small bobbinet dipper which should be washed with running tap water after each transfer.

The terminal pH, specific conductance and dissolved oxygen for each jar of the old series should be taken at the time the change is made for both the experimental and control jars. These data make possible comparison of the changes in the effluent made by the presence of the fish with those of the undisturbed solutions and also serve as a check against some unforeseen or unexpected happening which may have affected one or more jars of the series.

Theoretically, in the fixed volume bioassay method, both the accumulated waste products from the fish and the reduction of dissolved oxygen in the test solution by the respiratory activities of the animal unless aeration is maintained might be regarded as seriously affecting the accuracy of the results obtained. Actual tests, however, have shown that both of these factors can be disregarded if 4 liters of well-aerated fluid are used at the start, if but a single goldfish or top-minnow is carried in each jar, and if the fluid is changed daily.

Constant Flow Test

Constant flow tests have two conspicuous drawbacks— they require much larger volumes of the assay substances which may be difficult to obtain, particularly if it is a material which has been recovered from a complex effluent after laborious fractionation, and they require more attention and manipulation on the part of the observer. On the other hand, if ample material is available and if the apparatus is properly adjusted, there will be little or no accumulation of waste products throughout the system, the dissolved oxygen can be maintained at a fairly constant level and the tests can be conducted indefinitely without changing jars or fishes. The constant flow method is applicable to both warm and cold-water species.

The apparatus for constant flow assays can be arranged in many ways depending upon the choice of the operator and the kind of fishes used as test animals. Regardless of the specific details of the set-up, the requisites for constant flow bioassay tests are glass containers for the test fishes, provisions for constant inflow and outflow of the test solution, and a mixing device to insure the proper addition of effluent or test substances to the water supply. Wooden tanks, if they are properly aged so that no resin or wood extractives enter the test water, can be used for some types of material but the opportunities for contamination and loss of active principle are much greater than when glass jars, aquaria, or glass tanks are provided. Metal or painted metal troughs should be avoided as the test material may react with either the metal or the paint.

The authors have found a constant-flow siphon leading from the supply of effluent into a large carboy which also receives the constant flow of mixing water, to provide a very good mixing arrangement if the diluted effluent so obtained is led from the first carboy into a second carboy before it leaves through the glass tubes supplying the individual test jars or aquaria. It is, of course, absolutely essential to the success of the constant flow assay that a constant and measured flow of both the effluent and mixing waters is maintained throughout the test, otherwise, the dilution of the effluent cannot be measured and the test becomes valueless.

Almost any species of fish can be used in the constant flow apparatus but care must be taken to provide jars or aquaria large enough so that the test fishes will not feel the confinement nor become excited. It is also desirable for most species of fishes, excepting goldfishes and top-minnows, to cover the tops and sides of the aquaria so that the test fishes will be held in subdued light and will not be startled by shadows or sudden movements of the observers. It is well established that excited fishes are often more susceptible to many toxic materials than comparable fishes which have not been disturbed and which are resting quietly in semi-darkness.

BIOTIC SURVEYS

The evaluation of the analytical and bioassay data is always more dependable if supplemented with data concerning the biota of the stream, lake or impoundment. Various students of both polluted and unpolluted waters have proposed lists of index species and schemes of biological successions for the rapid appraisal of aquatic conditions. These lists and schemes make use of the differences in tolerance of certain species of plants and animals to various water characteristics, and are helpful in many specific cases. All such proposals are limited by the fact that the possible combinations of the many variables involved in aquatic complexes are too numerous to be classified readily in such systems. The approach is a valuable one, however, and the aquatic biologist should familiarize himself with the habitat preferences and physiological limitations of the more common aquatic species.

Campbell (1935) describes four zones in streams recovering from sewage pollution, namely the zone of recent pollution, the septic zone, the recovery zone, and the zone of cleaner water, listing index species for each zone. Tubificid worms, rat-tail maggots, and psychodids, in general, mark the zones unfavorable for fish, and in the recovery zone, the suckers, stonerollers, and shiners are the first fishes to reestablish themselves. Brinley (1942) and the United States Public Health Service (1944) define five zones on the basis of pollution, dissolved oxygen, plankton, algae, and fishes, as follows: the zone of heavy organic pollution, the zone of intermediate pollution, the fertile zone, the gamefish zone, and the poor fish zone. This classification, based on findings in the Ohio River system, is a very effective one for most inland streams.

As these and similar classifications are based on the biota as well as the analytical work, the observer should begin a short distance above the source of pollution (usually a mile will suffice) and continue the survey as far down stream as both the field studies and the analyses suggest. Too often the stream survey is discontinued too soon, that is, effects of the pollutant may appear in the waters much farther downstream than a cursory investigation would suggest. Four types of collections are recommended (1) plankton, (2) bottom fauna, (3) fish fauna, (4) marginal vegetation.

Plankton is readily measured for general studies by passing a measured quantity of water (several liters at least) through a fine plankton net, transferring the organisms with a little water to a graduated centrifuge tube, centrifuging at a low speed and reading the volume of the mass at the bottom of the tube. This value should be interpreted in terms of the volume of water from which the organisms were obtained. This procedure will give values at different stations which can be compared readily. If the observer is particularly interested in plankton, more elaborate counts and identifications can be made for limnological determinations but the gross volume of plankton (exclusive of the nannoplankton most of which will pass through the net) gives a fair picture of this unit of the biota. It must be remembered that the volume of river plankton is usually much less than that of lake plankton, but the comparisons of the polluted and unpolluted portions of the stream are still valid.

The bottom fauna varies greatly with the type of the bottom and the depth of the stream or lake. In the deeper portions, a bottom sample should be collected and the characteristics of the mud carefully noted. The sample should be diluted with water, screened, and the actual and relative numbers of the various forms of animals and plants recorded. This type of bottom sample is readily obtained with a Peterson dredge.

If the stream is shallow enough to permit, a Surber collector should be used. This consists of a hollow square of strip metal one-half or one meter on a side. This square is dropped onto the bottom of the stream and held in place while the observer turns all stones and rocks in the enclosed area and thoroughly disturbs the bottom to dislodge any animals living on the rocks and in the top layer of the bottom mud. These animals are swept into a fine net which is attached to the down-stream margin of the metal frame. In this way, approximately all of the insect larvae, small mollusca, crustaceans, and other forms in the area bounded by the frame are caught and quantitative measurements of the biological productivity of the stream floor obtained. Comparison of these measured catches from polluted and unpolluted portions of the stream often show striking differences.

The fishes of the stream should be caught by net and seine, an effort being made to obtain representatives of all species from all types of habitats. Only gross estimates of relative abundance are possible unless very extensive collections are made, but attention should be directed to the kinds of fishes found and the condition of individuals. Parasitism, the character of the flesh, the amount of fat, and the general appearance of the individual are helpful criteria for the evaluation of the fish fauna at each station.

The abundance and condition of the marginal or shore-line vegetation should be noted, as often the flora along the edge of the stream will give evidences of past catastrophies or of intermittant pollution not readily obtained otherwise.

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A

- Acetylene 87
  - Biological significance of 87
  - Determination of 87
- Acidity 47
  - Methyl orange phases 46
  - Mineral acid 48
  - Total 45, 48
- Activated sludge 7
- Alizarine method, fluorine 82
- Alkalinity 45
  - Bicarbonate 45, 46, 49
  - Hydroxide 45, 49
  - Normal carbonate 45, 46, 49
  - Phenophthalein 46, 49
  - Total 45, 49
- Aluminum 89
  - Determination of 89
  - Hydroxide 7
    - Flocculation by 6
- Amidol method, oxygen 21
- Ammonia 44, 65
  - Determination of 66
    - By distillation 67
    - By direct nesslerization 66
    - By Nessler method 66
  - Fixation for 4
  - Nitrogen 65
- Arsenic 89

B

- Bass, small-mouthed 104
- Benzidine method, sulfates 77
- Bioassays 102
  - Procedures 104
  - Test animals for 103
  - Water for 102
- Biotic surveys 107
  - Bottom fauna 108
  - Fishes 107
  - Index species 107
  - Plankton 108
  - Shoreline studies 109
- Bottle-train sampler 3, 6
- Brook trout 104
- Buffer 35
  - Solutions 35
    - Phosphate 67, 70
    - Potassium acid phthalate 35
  - Systems 45

C

- Calcium 63
  - Determination of 63
    - Oxalate method 63
    - Picrolonic method 64
  - Hardness 60
- Carbon dioxide 45, 48
- Carbonate 45, 49
  - Determination of 47
  - Hardness 60
- Carp 24, 103
- *Carassius auratus* 103
- Catfish 103
- Ceruleo-molybdic method, phosphates 79
- Chlorides 83
  - Determination of 83
  - Exploratory test for 91
- Chlorine 84
  - Biologic significance of 84
  - Determination of 84, 86
    - Orthotolidine method 84
    - Starch—iodine method 86
  - Exploratory test for 91
- Cyprinids 24, 103
- Citric acid 28
- Clarification 6
  - Aluminum hydroxide method 6
- Comparator block 39
- Conductance 29
  - Equivalent 29
  - Specific 29
    - Calculation of 34
    - Determination of 31
    - Temperature correction of 32
    - Samples for 3, 34
- Conductivity cells 32
- Cone, Imhoff 4, 59
- Constant flow tests 106
- Copper 74
  - Biological significance of 74
  - Determination of 74
- Crayfish 104
- Cresols 89
  - Biological significance of 89
  - Determination of 89
- Cyanides 89
  - Copper-sulfamic acid method 7

D

- Daphnia 18, 104
  - magna 104
- Dextrose 13, 16, 17, 28
- *Diatoms* 104
- Dichloro-diphenyl-trichloroethane, D.D.T. 96
- Dissolved oxygen (see oxygen) 5
- Dithizone method, zinc 76
- Dorosoma cepedianum 104

E

- Effluents 93
  - Bioassays of 96
  - Dilution tests of 94
  - Fractionation of 94, 97
    - By chemical separation 100
    - By dialysis 97
    - By distillation 99
    - By evaporation 99
    - By flocculation 99
    - By freezing 98
    - With non-miscible solvents 99
    - By precipitation 99
  - Hydrogen-ion concentration of 94
  - Oxygen demand of 95
  - Samples of 5, 101
  - Specific conductance of 95
- Electrodes 31, 34
  - Conductance 31
  - Glass 34
  - KCl-calomel 35
- Ephemeridae 104
- Exploratory tests 90

F

- Fiddler 103
- Fish berries 96
- Fixation of samples 4
- Flocculation 6, 16, 66
  - By aluminum hydroxide 6
  - By copper-sulfamic acid 7
- Fluorescence 92
- Fluorides 81
  - Biological significance of 81
  - Determination of 82
- Foerst sampler 2, 6, 33
- Formulae 12, 58
  - For dissolved oxygen 12
  - For light penetration 58
  - For sample volume correction 12
- Fuller's earth 58

G

- *Gambusia patruelis* 103
- Gammarids 104
- Gizzard shad 104
- Glass electrode 34
  - Range of 37
  - Salt error of 37

- Glucose 13, 16, 17, 28
- Goldfish 18, 103

H

- Hardness 60
  - Carbonate 60
  - Determination of 60
  - Non-carbonate 61
  - Sulfate 60
  - Total 62
- Humic acid 47
- Hydrogen-ion concentration, pH 34
  - Colorimetric determination of 37
    - Gillespie method 38
    - Spotting tests 41
  - Evaluation of 42
  - Glass electrode determination of 34
    - Range of 37
    - Salt error of 37
- Hydroxyquinoline method, magnesium 65

I

- *Ictalurus punctatus* 103
- Imhoff cone 4, 59
- Index species 107
- Indicators
  - Litmus 62
  - Methyl orange 46, 51, 63, 75
  - pH 43
  - Phenophthalein 46, 51, 70
  - Xylene cyanole-methyl orange 48, 51
- Iron 46, 71
  - Determination of 71
  - Dissolved, limits of 71
  - Exploratory test for 91
  - Ferric 15, 72
    - Determination of 72
    - Interference of 15
  - Ferrous 15, 72
    - Determination of 72
    - Interference of 15
  - Suspended 4, 71
  - Total 72

K

- Kemmerer sampler 2
- Kjeldahl method, organic nitrogen 68

L

- Lactic acid 28, 44
- Lather factor 62
- Lead 89
- *Lepomis humilis* 104
- Light penetration 58
- Loch Leven trout 104

M

- Magnesium 29, 65
  - Determination of 65
    - Hydroxylquinoline method 65
    - Phosphate method 65
  - Hardness 61
  - Pyrophosphate 65
  - Sulfate 30
- Manganese 73
  - Determination of 73
  - In natural waters 73
- Mayfly larvae 104
- *Micropterus dolomieu* 104
- Minimal lethal dose 101
- Mud 6, 71, 108
  - Suspensions of 6
  - Iron in 4, 71

N

- Nessler's method, ammonia 66
  - By distillation 67
  - By direct nesslerization 66
- Nitrites 13, 16, 18
  - Interference by 13
  - Removal of 18
- Nitrogen 65
  - Ammonia 65
  - Organic 68

O

- *Oncorhynchus kisutch* 104
- Orange-spotted sunfish 104
- Organic compounds 11, 16, 28
  - Interference of 16
  - Tests for 16
- Orthotolidine method, chlorine 85
- Oxalate method, calcium 63
- Oxygen 5
  - Consumed 25
  - Demand 25
  - Dissolved 5
    - Computation 12
    - Determination of 10
      - Amidol method 21
      - Winkler procedures 10
        - Basic method 11
        - Rapid sample blank 14
        - Rapid unmodified 13
        - Sample blank 13
        - Sulfamic acid 18
    - Evaluation of 23
    - Interfering substances 15
    - Orientation tests for 15
    - Samples for 2, 6

P

- Pacific salmon 104
- Particle size 58
- Pentachlorophenol 89
- *Perca flavescens* 104
- pH (see Hydrogen-ion concentration 34
- Phenols 89
- Phosphate 79
  - Determination of 79
  - Exploratory test for 91
  - In natural waters 80
  - Method for magnesium 65
  - Total phosphates 80
- Picrolonic acid method, calcium 64
- Picrotoxin 96
- Pollution hazards 100
- Polythionates 15
- Potassium 29
  - Chloroplatinate 68
  - Permanganate 28
    - Method for oxygen consumed 26
    - Number 26
- Pyrogallic acid 90

R

- Reagent
  - Acetone 100
  - Acid
    - Acetic 87, 89
    - Acetic, glacial 87
    - Benzoic 34
    - Chloroplatinic 33
    - Hydrochloric 18, 41, 64, 73, 75, 77, 78, 79, 81, 82, 85, 91
    - Nitric 80, 84, 88, 91
    - Phosphoric 74
    - Sulfamic 7, 18
    - Sulfamic, reagent 21
    - Sulfuric 18, 29, 33, 51, 63, 64, 70, 81
  - Alcohol
    - Amyl 99
    - Ethyl 41, 62, 99
  - Alkaline iodide reagent 20
  - Amidol 23
  - Ammonia water 65
  - Ammonium
    - Chloride 64, 70
    - Citrate 75
    - Hydroxide 64, 76, 88, 90, 91
    - Molybdate 81, 91
    - Oxalate 28, 64
    - Thiocyanate 88

- Benzidine hydrochloride 78, 91
- Brom-cresol
  - Green 38, 43
  - Purple 38, 43
- Brom-phenol blue 43
- Brom-thymol blue 64
- Bromine water 64
- Calcium
  - Carbonate 62
  - Chloride 62
- Carbon
  - Disulfide 99
  - Tetrachloride 75, 77, 99
- Chloroform 4, 71, 99
- Cobaltus chloride 22
- Copper
  - Standard solution 75
  - Sulfate 70, 75
- Cresol red 43
- Diaminophenol hydrochloride 23
- Diphenylthiocarbazone 77
- Dithizone reagent 77
- Ether, ethyl 99
- Ferric
  - Ammonium alum 88
  - Ammonium sulfate 73, 88
  - Nitrate 84
- Ferrous
  - Ammonium sulfate 73
- Fuller's earth 58
- Hydrogen peroxide 71
- Iodine 70
  - Solution 18, 19
- Iodized alkaline iodide reagent 20
- Lauryl sulfate 23
- Lead acetate 33, 70
- Litmus 62
- Manganous
  - Chloride 20
  - Sulfate 20
- Mercuric chloride 70
- Mercury, metallic 9, 70
- Methyl orange 51, 63, 75
- Nessler's reagent 70
- Orthotolidine 86
  - Dihydrochloride 86
- Reagent 86
- Phenol red 43
- Phenolphthalein 51, 70
- Phosphate standard 81
- Potassium
  - Acid phthalate 35
  - Chloride 34
  - Chromate 84
  - Dichromate 20, 22
  - Hydroxide 20, 70
  - Iodide 20, 70, 87, 91
  - Periodate 74
  - Permanganate .. 28, 64, 73, 74, 91
  - Persulfate 70
  - Phosphate
    - Diacidic 43, 70, 81
    - Dibasic 70
    - Monobasic 43, 70, 81
  - Sodium tartrate 70
  - Thiocyanate 73, 91
- Rochelle salt 70
- Silver nitrate 84, 88, 91
- Soap
  - Castile 62
  - Solutions 62
- Sodium
  - Alizarine monosulphonate 83
  - Carbonate 38, 63
  - Chloride 84
  - Citrate 23, 76
  - Diethyldithiocarbamate 75
  - Fluoride 83
  - Hydroxide ...40, 51, 63, 70, 78, 79
  - Nitrate 79
  - Nitrite 89
  - Nitroferricyanide 91
  - Orthophosphate, dibasic 71
  - Phosphate, dibasic 65, 71
    - Thiocyanate 84
    - Thiosulphate 19, 77, 87
  - Stannous chloride 81, 91
  - Starch solution 21, 71, 87, 91
- Thymol blue 38, 43
  - Tin, mossy 81
  - Toluene 4
  - Water, ammonia-free 69
  - Xylene cyanole-methyl orange 51
  - Zirconium
    - Alizarine reagent 83
    - Nitrate 83
    - Oxychloride 83
- Reagents
  - For determination of
    - Acetylene 88
    - Acidity 51
    - Alkalinity 51
    - Calcium 64
    - Chlorides 84, 91
    - Chlorine 86, 87, 91
      - By orthotolidine 86
      - By starch-iodide 87
    - Copper 75
    - Fluorides 82
    - Hydrogen-ion 34, 40
    - Iron 73, 91
    - Magnesium 65
    - Manganese 74
    - Nitrogen 69
    - Oxygen
      - By amidol 23
      - By Winkler method 18
    - Oxygen consumed 28
    - Phosphates 81
    - Sulfur
      - Non-sulfate 79
      - Sulfate 78
    - Zinc 76
- Recovery zones 107

S

- Salicylic acid 28, 90
- *Salmo*
  - *Irideus* 104
  - *Levensis* 104
- Salt error 37
- *Salvelinus fontinalis* 104
- Sample bottles 7
  - Glass stoppered 9
  - Magnesium citrate 10
  - Precision 7
- Sampler
  - Bottle-train 3
  - Foerst 2
  - Kemmerer 2
- Samples 1
  - Effluent 5
  - Water 1
- Sedimentation 52
  - Rate 53
  - Tubes 53
- Selenium 90
- Sewage 7, 52, 59, 107
- Silicon 80
- Siphon sampling 3
- Soap method, hardness 61
- Sodium
  - Diethyldithiocarbamate method, copper 74
  - Pentachlorophenate 89
- Specific conductance 29
- Spotting tests 41, 90
  - Starch-idide method, chlorine 86
- Succinic acid 28
- Sulfates 77
  - Determination of 77
  - Exploratory test for 91
  - In natural waters 77
- Sulfides 78
  - Determination of 78
  - Exploratory test for 91
  - Interference by 15

Sulfites 78
  Determination of 78
  Interference by 15
Sulfur, non-sulfate 78
Sulphanilic acid 28, 90
Suspended matter 51
  Determination of 52
  Flocculation 6
  Samples for 4

T

Tannic acid 44, 47, 90
Tartaric acid 28
Test animals 103
Tests, exploratory 90
Top-minnow 103
Trade wastes (see effluents) 93
Trout 104
  Brook 104
  Loch Leven 104
  Rainbow 104
Turbidity 55
  Evaluation of 58
  Determination of 55
  Samples for 4

U

Ultraviolet light 92
Urea 28

W

Water
  Ammonia-free 69
  For bioassays 102
  Hardness of 60
  Quality 1
  Samples 1
    Clarification of 6
    Collection of 1
    Fixation of 1, 4
Winkler procedures 10

X

Xylene cyanole-methyl orange 51

Z

Zinc 75
  Biological significance of 75
  Determination of 76
  Fluorescence of 92

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STUDY OF THE ALASKA TUNDRA WITH REFERENCE TO ITS REACTIONS TO REINDEER AND OTHER GRAZING

RESEARCH REPORT 10

UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary
FISH AND WILDLIFE SERVICE
Ira N. Gabrielson, Director

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STUDY OF THE ALASKA TUNDRA WITH REFERENCE TO ITS REACTIONS TO REINDEER AND OTHER GRAZING

BY

LAWRENCE J. PALMER and CHARLES H. ROUSE

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ABSTRACT

THE ALASKA TUNDRA varies in width from a few miles to 200 miles along the Bering Sea and from 100 to 150 miles along the Arctic coast. Plant composition is largely lichens, grasses, sedges, alpines, and shrubs, of which 16 distinct vegetative types are described in this report.

Studies were initiated in 1920 to work out the principal range and range requirements of the reindeer. Subsequent disturbance by grazing and fire, accompanied by climatic changes, has resulted in general confusion in plant mixture and occupation. Recovery of lichen range, injured by grazing or fire, may require from 20 to 40 years for restoration to original density and height. Reestablishment of vascular plants is rapid. Moderate grazing by open herding and rotational use will permit sustained utilization of undamaged tundra.

STUDY OF THE ALASKA TUNDRA WITH REFERENCE TO ITS REACTIONS TO REINDEER AND OTHER GRAZING

By LAWRENCE J. PALMER and CHARLES H. ROUSE, formerly *biologists, Section of Biological Surveys, Division of Wildlife Research, Fish and Wildlife Service* [1]

CONTENTS

Page
Introduction 1
List of tundra plants.................. 4
Grasses 4
Grasslike plants 4
Forbs (herbaceous plants)........... 4
Shrubs (woody plants)............... 6
Mosses 6
Lichens 7
Method of study....................... 7
Types of tundra vegetation............ 8
Beach-transition type 8
Sand-dune type 11
Coast-sandspit grass-weed type.... 13
Coast-sandspit lichen-browse type.. 14
Coast-tundra sedge-browse type.... 16
Tundra-lichen type 18
Wet-tundra sedge-lichen type...... 26
Wet-tundra sedge type.............. 28

Page
Types of tundra vegetation—Continued.

Grass-browse type 29
Heath type 31
Lichen-browse type 33
Woodland-moss type 36
Alpine-dryas type 38
Overgrazed-tundra browse-lichen type 40
Overgrazed-tundra sedge-weed type 41
Overgrazed browse-grass type...... 42
Denuded corral sites................ 44
Unalakleet-Egavik Reindeer Allotment, Bering Sea coast............ 45
Kokrines Reindeer Allotment, lower Yukon River............... 45
Summary and conclusions............. 45
Management of reindeer on Nunivak Island 48

INTRODUCTION

During an investigation of the reindeer in Alaska by the Bureau of Biological Survey (now the Fish and Wildlife Service), begun in 1920 and continued to 1935, a study was made of the tundra because it constitutes the principal range of the reindeer. Numerous permanent and temporary quadrats were established for the observation of plant succession and reaction to grazing. This report summarizes the results of the study and considers the problem of reindeer-musk ox range use for the period subsequent to 1944.

In a general way Alaska may be said to possess three main classes of vegetative cover: (1) Coast forest; (2) woodland, or boreal forest; and (3) tundra.[2] The coast forest is confined to, and is the prevailing type in, southeastern Alaska and the Prince William Sound region. The boreal forest covers much of the nterior of northern and western Alaska. The tundra is a tree-ess, prairielike region characteristic of the Arctic and Subarctic

---

[1] The writers wish to acknowledge the valued assistance of William Byron Miller, ormerly in the Alaska work of the Bureau of Biological Survey, who carried on much of the field work between the years 1925 and 1930. [The senior author, Lawrence J. Palmer, died at Anchorage, Alaska, June 20, 1945, while this publication was in press.]

[2] Plant Ecology, by Weaver and Clements. Second edition, pp. 482-491. 1938.

Zones. It occurs chiefly in a broad belt bordering the Bering S and Arctic Ocean and extends from the Aleutian Islands nort ward to Point Barrow and thence eastward along the Arctic coa into Canada.

The tundra belt, of flat to rolling topography, varies in wid from a few miles to approximately 200 miles along the Beri Sea. On the Arctic coast it reaches inland to include the foothil of the Brooks Range, a distance varying between 100 and 1 miles. Extensive patches of tundra also occur in the mounta valleys and uplands of the central interior. The interior tund is similar in composition to that of the coast although in man places it contains a greater proportion of lichens, grasses, an shrubs. It is also generally drier. In the heavily forested sout eastern part of Alaska are many small, semiswamp areas that a tundralike in appearance. These are called "muskegs" and diff from the true tundra in having a flat rather than a hummock surface and a greater proportion of mosses, grasses, and sedge This use of the term "muskeg" is local; elsewhere hummocks a considered typical of muskeg.

The tundra merges gradually into the boreal forest so the occurs a transition type of cover composed of open tree growt with an undercover of tundra vegetation. This overlapping zon essentially tundra in forage values, is included in the tundra be as here treated (fig. 1). It has been recognized that the fore is slowly advancing onto the tundra.[3]

At a number of places on the Bering Sea and Arctic coasts th spruce is now on, or within a few miles of, salt water. At Unalakleet, on Norton Sound, for example, the trees are within miles of the beach. At Foothill, Bonanza, and Isaac's Point o Norton Bay the spruce comes to the water's edge; and in Kotzebu Sound at the mouths of the Buckland, Selawik, Kobuk, an Noatak Rivers the forest cover reaches within about 25 miles o tidewater.

A characteristic of the major part of the tundra is its hummocky surface, not unlike that of a wet meadow much trample by livestock. Locally the hummocks are called "niggerheads. They vary in size and shape, but are often so uniform in a localit that when viewed from a distance the ground has a level appearance. Furthermore, on account of the heavy cover of vegetatio the irregular surface may not be apparent until one enters th area. Hummocks may be from a few inches to knee high, ofte so closely spaced as to make walking difficult. Circular in form the hummocks vary in diameter from 8 inches or less to a foo or more.

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[3] The Edge of the Forest in Alaska and the Reason for its Position, by Robert F Griggs. Ecology 15 (2): 80-96, April 1934.

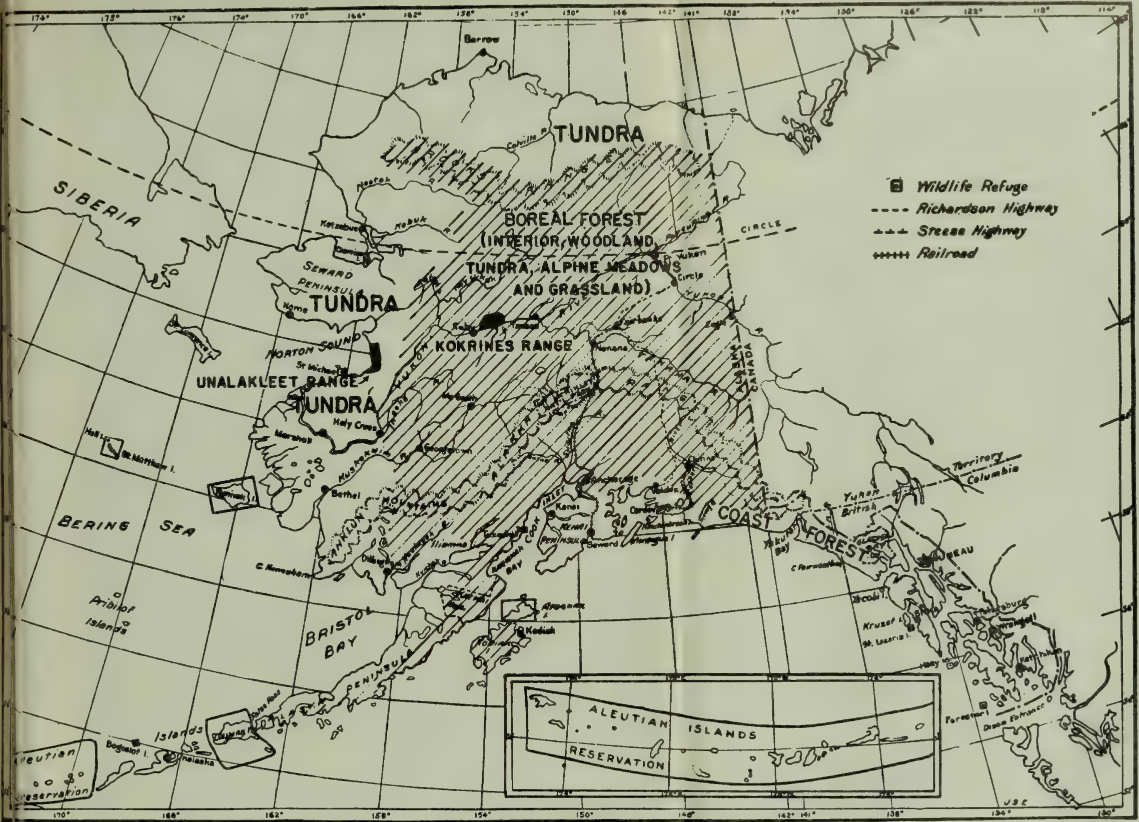

Figure 1.—Distribution of Alaskan vegetative type-cover in general and approximate location of the tundra.

On the lower elevations, especially near the coast, the soil of the tundra is often wet or moist. Puddles of water frequently are found in the interstices between the niggerheads, and numerous small ponds and lakes break the otherwise uniform expanse of deep green cover. Even on as much as a 30-degree slope this condition of wet ground with puddles between the hummocks may sometimes be noted. Flat bogs often are found in the valley bottoms. On better drained areas, away from the coast, a drier condition prevails and the ground is less hummocky. Thus a dry and a wet tundra type are recognized.

The predominating soils of the tundra include a black sandy loam and a sandy-clay loam and intermixtures over a blue-clay subsoil. They are rich in humus and often become peatlike in texture. Rocky areas on the crests of ridges or on the beach are chiefly of gravelly sandstone, quartz, limestone, or, in places, of igneous rocks of recent volcanic origin. On the coastal tundra, permanent frost occurs 1 to 3 feet below the surface, and in some sections, as at Kotzebue Sound, Wainwright, and Barrow, solid ice is found under the soil at a depth of 2 to 3 feet. Moisture furnished by standing water, frost and ice below the surface, prevailing fogs along the coast, and frequent rainfall during the growing season favor luxuriant vegetation throughout the tundra.

Ordinarily, except for water areas and rocky ridge tops, the surface is completely covered with vegetation. The plant composition includes a mixture of lichens, mosses, grasses, forbs (any herbs other than grass), and shrubs, the immediate coast range having a predominance of sedges (*Carex* and *Eriophorum*) and shrubs, and the inland areas a preponderance of lichens and shrubs. Because of differing conditions of exposure, soil, moisture, and the physical nature of the ground, the plant mixture varies greatly. Innumerable combinations occur, presenting a complexity of pattern; and while one may recognize the dry tundra of the interior and the wet tundra of the coastal region, there s a considerable intermixture of minor types in response to varying soil and moisture within each of those major divisions of the formation.

LIST OF TUNDRA PLANTS

The plants[4] most frequently found on the tundra include th following:

GRASSES

Agropyron sericeum (wheatgrass)
Agrostis aequivalvis (bentgrass)
Agrostis borealis (bentgrass)
Alopecurus alpinus (alpine foxtail)
Arctagrostis latifolia
Calamagrostis canadensis scabra (coast bluejoint)
Deschampsia caespitosa (tufted hairgrass)
Elymus mollis (American dunegrass
Festuca rubra (red fescue)
Festuca rubra lanuginosa (fescue)
Hierochloe alpina (sweetgrass)
Phleum alpinum (alpine timothy)
Poa arctica (Arctic bluegrass)
Poa eminens (giant bluegrass)
Poa hispidula (bluegrass)
Trisetum spicatum (spike trisetum)

GRASSLIKE PLANTS

Carex aquatilis (sedge)
Carex atrofusca (sedge)
Carex canescens (sedge)
Carex compacta (sedge)
Carex concolor (sedge)
Carex heleonastes (sedge)
Carex lachenali (sedge)
Carex macrochaeta (sedge)
Carex membranacea (sedge)
Carex rotundata (sedge)
Carex scirpoidea (sedge)
Equisetum arvense (horsetail)
Equisetum palustre (horsetail)
Equisetum sylvaticum (horsetail)
Eriophorum angustifolium (large cotton-sedge)
Eriophorum callithrix (small cotton-sedge)
Eriophorum vaginatum (cotton-sedge
Juncus castaneus (rush)
Juncus haenkei (rush)
Luzula arcuata (woodrush)
Luzula kjellmanniana (woodrush)
Luzula multiflora (woodrush)
Sparganium hyperboreum (burreed)

FORBS (HERBACEOUS PLANTS)

Achillea borealis (yarrow)
Aconitum delphinifolium (monkshood)
Allium sibiricum (onion)
Amsinckia menziesi (fiddleneck)
Androsace chamaejasme
Anemone multiceps (anemone)
Anemone narcissiflora (anemone)
Anemone parviflora (anemone)
Anemone richardsoni (anemone)
Antennaria borealis (everlasting)
Antennaria monocephala (everlasting)
Arenaria arctica (sandwort)
Arenaria macrocarpa (sandwort)
Arenaria physodes (water starwort)
Arenaria verna (sandwort)
Arnica alpina (arnica)
Arnica nutans (arnica)
Arnica obtusifolia (arnica)
Arnica unalaschensis (arnica)
Artemisia arctica (wormwood)
Artemisia semavinensis (wormwood)
Artemisia tilesii (wormwood)
Aster sibiricus (aster)
Astragalus alpinus (loco)
Astragalus littoralis (loco)
Barbarea orthoceras (wintercress)
Barbarea vulgaris (wintercress)
Bupleurum americanum (hares-ear)
Caltha natans (marshmarigold)
Caltha palustris arctica (marshmarigold)
Campanula lasiocarpa (bellflower)
Campanula rotundifolia (bellflower)
Campanula uniflora (bellflower)
Capsella bursa-pastoris (shepherds purse)
Cardamine bellidifolia (bittercress)
Cardamine blaisdellii (bittercress)
Cardamine pratensis (bittercress)
Cardamine purpurea (bittercress)
Cardamine umbellata (bittercress)
Castilleja tristis (paintbrush)
Cerastium alpinum (chickweed)
Cerastium arcticum (chickweed)
Cerastium minimum (chickweed)
Cheirinia cheiranthoides (wallflower
Chrysanthemum arcticum (daisy)
Chrysanthemum integrifolium (daisy
Chrysosplenium beringianum (golde saxifrage)
Chrysosplenium tetrandrum (golde saxifrage)
Cicuta douglasi (waterhemlock)
Claytonia eschscholtzi (springbeauty

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[4] Grateful acknowledgment is made to Dr. Sidney F. Blake and Jason R. Swallen, o the Bureau of Plant Industry, United States Department of Agriculture, and to Emer C. Leonard, of the Division of Plants, United States National Museum, for checking th names of plants.

FORBS (HERBACEOUS PLANTS)—Continued

ytonia sarmentosa (springbeauty)
ytonia tuberosa (springbeauty)
chlearia fenestrata (spooncress)
chlearia oblongifolia (spooncress)
elopleurum gmelini (parsnip)
nioselinum gmelini (hemlock parsey)
stopteris fragilis (brittle fern)
stopteris montana (brittle fern)
lphinium blaisdelli (larkspur)
lphinium browni (larkspur)
nthus repens (pink)
entra pauciflora
decatheon frigidum (shootingstar)
aba alpina (whitlow)
aba borealis (whitlow)
yas octopetala (dryad)
yopteris dilatata (shield fern)
yopteris fragrans (shield fern)
ilobium anagallidifolium (willow-weed)
ilobium angustifolium (common ireweed)
ilobium bongardi (willow-weed)
ilobium latifolium (broadleaf wilow-weed)
igeron hyperboreus (daisy)
igeron uniflorus (daisy)
itrichium arctioides (Arctic forget-ne-not)
lium boreale (bedstraw)
ntiana frigida (gentian)
ntiana glauca (gentian)
ntiana propinqua (gentian)
ntiana prostrata (gentian)
ntiana tenella (gentian)
benaria bracteata (orchid)
benaria hyperborea (orchid)
benaria obtusata (orchid)
dysarum americanum (jointpod)
dysarum mackenzi (jointpod)
racleum lanatum (cow-parsnip)
ppuris vulgaris (marestail)
nkeneya peploides (sea-beach sandwort)
s setosa (Arctic iris)
gotis minor
thyrus maritimus (beach pea)
squerella arctica (bladderpod)
justicum macouni
justicum scoticum (Scotch lovage)
naea borealis (twinflower)
ydia serotina
matogonium rotatum
pinus (lupine)
chnis apetala (campion)
copodium alpinum (clubmoss)
copodium annotinum (clubmoss)
copodium selago (clubmoss)
tricaria hookeri (camomile)
tricaria matricarioides (camomile)
nyanthes trifoliata (buckbean)
rtensia eastwoodae (bluebells)
rtensia maritima (beach bluebells)
Mertensia paniculata (timber bluebells)
Moehringia lateriflora (trailing sandwort)
Montia rivularis (springbeauty)
Myosotis alpestris (forget-me-not)
Oxyria digyna (mountain sorrel)
Oxytropis campestris (oxytrope)
Oxytropis mertensiana (oxytrope)
Oxytropis nigrescens (oxytrope)
Oxytropis podocarpa (oxytrope)
Oxytropis sewardensis (oxytrope)
Papaver nudicaule (Iceland poppy)
Papaver nudicaule multiceps (Iceland poppy)
Parnassia kotzebuei
Parrya nudicaulis (Parry mustard)
Pedicularis arctica (fernweed)
Pedicularis capitata (fernweed)
Pedicularis labradorica (fernweed)
Pedicularis langsdorfi (fernweed)
Pedicularis parviflora (fernweed)
Pedicularis sudetica (fernweed)
Pedicularis versicolor (fernweed)
Pedicularis verticillata (fernweed)
Pentstemon procerus
Petasites frigida (butterbur)
Phlox sibirica (phlox)
Pinguicula vulgaris (butterwort)
Polemonium acutiflorum
Polemonium humile
Polygonum alaskanum (smartweed)
Polygonum aviculare (knotweed)
Polygonum bistorta (smartweed)
Polygonum plumosum (smartweed)
Polygonum viviparum (smartweed)
Potentilla biflora
Potentilla egedii (fivefinger)
Potentilla elegans (showy fivefinger)
Potentilla emarginata (fivefinger)
Potentilla fruticosa (shrubby cinquefoil)
Potentilla nivea (small woolly cinquefoil)
Potentilla palustris (marsh fivefinger)
Potentilla uniflora (fivefinger)
Primula borealis (primrose)
Primula egaliksensis (primrose)
Primula eximia (primrose)
Primula sibirica (primrose)
Pyrola grandiflora
Ranunculus chamissonis (buttercup)
Ranunculus hyperboreus (buttercup)
Ranunculus nivalis (buttercup)
Ranunculus pallasii (water buttercup)
Ranunculus pygmaeus (buttercup)
Ranunculus sceleratus (buttercup)
Ranunculus sulphureus (buttercup)
Ranunculus verticillatus (buttercup)
Rhinanthus crista-galli (yellow rattle)
Roripa palustris (marshcress)
Rumex acetosa (sour dock)
Rumex occidentalis (dock)
Rumex occidentalis nanus (dock)
Sagina saginoides (pearlwort)

FORBS (HERBACEOUS PLANTS)—Continued

Sanguisorba microcephala (burnet)
Sanguisorba sitchensis (Alaska burnet)
Saussurea monticola (sawwort)
Saussurea subsinuata (purple aster)
Saxifraga bracteata (saxifrage)
Saxifraga bronchialis (saxifrage)
Saxifraga cernua (saxifrage)
Saxifraga eschscholtzii (saxifrage)
Saxifraga flagellaris (saxifrage)
Saxifraga foliolosa (saxifrage)
Saxifraga hieracifolia (saxifrage)
Saxifraga hirculus (saxifrage)
Saxifraga neglecta (saxifrage)
Saxifraga nelsoniana (saxifrage)
Saxifraga oppositifolia (saxifrage)
Saxifraga radiata (saxifrage)
Saxifraga rivularis (saxifrage)
Saxifraga serpyllifolia (saxifrage)
Saxifraga unalaschensis (saxifrage)
Sedum integrifolium (stonecrop)
Selaginella schmidti (selaginella)
Senecio atropurpureus (senecio)
Senecio frigidus (senecio)
Senecio lugens (senecio)
Senecio palustris (senecio)
Senecio pseudo-arnica (senecio)
Senecio resedifolius (senecio)
Senecio walpolei (senecio)
Sieversia glacialis
Sieversia rossi
Silene acaulis (moss campion)
Smelowskia calycina
Solidago multiradiata (goldenrod)
Sophia sophioides (tansymustard)
Statice arctica (thrift)
Stellaria longipes (starwort)
Stellaria media (starwort)
Taraxacum lyratum (dandelion)
Taraxacum officinale (dandelion)
Thalictrum alpinum (meadowrue)
Tofieldia coccinea (false asphodel)
Tofieldia palustris (false asphodel)
Trientalis europaea arctica (star flower)
Valeriana capitata (valerian)
Veratrum spicatum (false-hellebore
Veronica stelleri (speedwell)
Vicia (vetch)
Viola biflora (violet)
Viola palustris (violet)
Woodsia glabella
Zygadenus elegans (deathcamas)

SHRUBS (WOODY PLANTS)

Alnus alnobetula (alder)
Andromeda polifolia (bog-rosemary)
Arctous alpina (alpine bearberry)
Betula kenaica (birch)
Betula rotundifolia (ground birch)
Cassiope tetragona (moss heather)
Cornus suecica (herb dogwood)
Diapensia lapponica (diapensia)
Empetrum nigrum (crowberry)
Ledum decumbens (Alaska tea)
Ledum groenlandicum (Alaska tea)
Ledum palustre (Alaska tea)
Rhododendron lapponicum (rhododendron)
Ribes triste (red currant)
Rosa acicularis (rose)
Rubus arcticus (Arctic raspberry)
Rubus chamaemorus (salmonberry)
Salix arctica (Arctic willow)
Salix fuscescens (bog willow)
Salix glauca (grayleaf willow)
Salix glauca aliceae
Salix phlebophylla (skeleton willow)
Salix pulchra (diamondleaf willow)
Salix reticulata (netleaf willow)
Salix richardsoni (Richardson willow)
Salix rotundifolia (roundleaf willow)
Spiraea steveni (spiraea)
Vaccinium oxycoccos (small cranberry)
Vaccinium uliginosum (blueberry)
Vaccinium vitis-idaea (mountain cranberry)
Viburnum pauciflorum (highbush cranberry)

MOSSES

Aulacomnium palustre (bunch moss)
Aulacomnium turgidum (bunch moss)
Brachythecium rivulare
Bryum albicans (common moss)
Bryum bimum (common moss)
Calliergon alaskanum
Calliergonella cuspidata
Climacium americanum
Dicranum bonjeani (pad moss)
Dicranum elongatum (pad moss)
Dicranum groenlandicum (pad moss)
Dicranum scoparium (pad moss)
Dicranum spadiceum (pad moss)
Drepanocladus fluitans (fern moss)
Drepanocladus uncinatus (fern moss)
Funaria hygrometrica
Hypnum schreberi
Leptobryum pyriforme
Mnium glabrescens
Oligotrichum laevigatum
Paludella squarrosa
Philonotis fontana
Polytrichum commune commune (heath moss)
Polytrichum commune yukonense (heath moss)
Polytrichum juniperinum (heath moss)
Polytrichum piliferum hyperboreum (heath moss)

MOSSES—Continued

Polytrichum piliferum piliferum (heath moss)
Polytrichum strictum (heath moss)
Ptilidium ciliare
Rhacomitrium lanuginosum
Sphagnum angstroemii (sphagnum moss)
Sphagnum capillacexum tenellum (sphagnum moss)
Sphagnum fimbriatum (sphagnum moss)
Sphagnum girgensohni (sphagnum moss)
Sphagnum lindbergi (sphagnum moss)
Sphagnum magellanicum (sphagnum moss)
Sphagnum plumosum (sphagnum moss)
Sphagnum riparium (sphagnum moss)
Sphagnum squarrosum (sphagnum moss)
Tetraplodon mnioides

LICHENS

Alectoria nigricans
Alectoria ochroleuca
Cetraria chrysantha
Cetraria cucullata
Cetraria islandica
Cetraria islandica crispa
Cetraria islandica platyna
Cetraria nivalis
Cladonia amaurocraea
Cladonia amaurocraea celotea
Cladonia amaurocraea oxyceras
Cladonia bellidiflora
Cladonia coccifera
Cladonia crispata
Cladonia decorticata
Cladonia degenerans
Cladonia delessertii
Cladonia furcata
Cladonia gracilis
Cladonia gracilis dilatata
Cladonia gracilis ecmocyna
Cladonia gracilis elongata
Cladonia rangiferina
Cladonia squamosa muricella
Cladonia sylvatica
Cladonia sylvatica sylvestris
Cladonia uncialis
Cladonia uncialis obtusata
Cladonia uncialis turgescens
Dactylina arctica
Nephroma arcticum
Ochrolechia spp.
Parmelia spp.
Sphaerophorus coralloides
Stereocaulon alpinum
Stereocaulon coralloides
Stereocaulon tomentosum
Sticta linita
Thamnolia vermicularis

Of the plants listed, the *Carex* and *Cladonia* species are dominants in the tundra climax. Subdominants include species of *Eriophorum, Ledum, Salix* and *Betula* (low-growing forms), *Vaccinium, Empetrum nigrum, Arctous alpina,* and *Rubus chamaemorus.* Prominent grasses are *Festuca, Poa, Arctagrostis,* and *Agrostis.* The most common mosses are *Sphagnum* and *Polytrichum.* Characteristic forbs include species of *Pedicularis, Polygonum, Chrysanthemum, Arnica, Gentiana, Saxifraga, Senecio, Polemonium, Campanula,* and the Arctic coltsfoot (*Petasites frigida*).

METHOD OF STUDY

In study of the tundra by the quadrat method, various treatments were employed to simulate grazing by reindeer. These were applied to each important type of tundra vegetation. They included picking lichens by hand to imitate complete cropping, cutting the vegetation at different heights to represent various degrees of utilization, denuding by spading up and removing all the plant cover to simulate extreme overgrazing, trampling and grazing by livestock, and protecting from disturbance as a check. Recording included listing and charting or estimating the plant density and composition.

TYPES OF TUNDRA VEGETATION

Quadrats were established on several types of tundra vegeta tion and observations were made on them.

BEACH-TRANSITION TYPE

CAPE ETOLIN

Two beach-transition types are being studied. The first o these is located at Cape Etolin, north side of Nunivak Island near latitude 60° 15′ N., and longitude 166° 5′ W., in Bering Sea The soil is of fine, deep, well drained, wind-blown sand with very little humus. Moisture conditions, on account of frequent rains and fogs during the summer, are extremely favorable for plant growth. The vegetation is composed of *Elymus mollis, Epilobium latifolium, Artemisia arctica, Achillea borealis, Coelopleurum gmelini, Empetrum nigrum, Stereocaulon tomentosum,* and the mosses, *Polytrichum* and *Bryum.* These make vegetative cover of 0.9 to 1.0 density.[5]

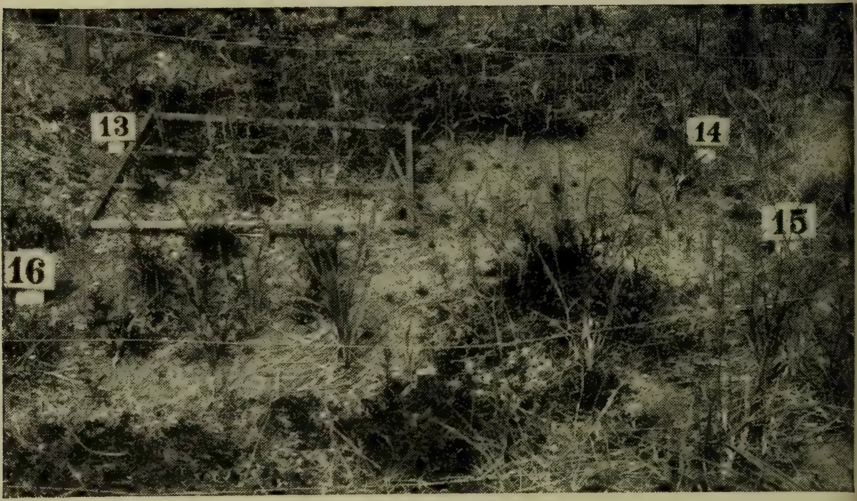

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Figure 2.—Beach-transition type exclosure on Nunivak Island. July 4, 1929.

A fenced exclosure (fig. 2) containing four 1-meter-square quadrats was erected in this type in 1927. Two of the quadrats were undisturbed, on the third the vegetation was removed by cutting it at the ground surface with a sharp knife, and the fourth was denuded by spading.

Denuded quadrat.—Observations indicate that the initial phase of plant succession on the denuded quadrat is an association of *Elymus mollis, Epilobium latifolium,* and *Artemisia arctica.* A few plants of *Achillea, Mertensia,* and *Coelopleurum* also were present. *Empetrum* and *Stereocaulon* were early invaders, spread-onto the denuded area from adjacent ground, *E. nigrum* ıg a prominent species in the nearby tundra association.[6] e years after denudation of the quadrat the vegetative cover found to be of 0.7 density, half of it *Empetrum nigrum.* *mus mollis* was proportionately as abundant as on the undis- ɔed areas, but did not appear so thrifty, as no seed heads were ıg produced. Sphagnum moss appeared in the later stage he succession, and lichens receded as *Sphagnum* and *Empe- n* increased. The herbaceous weed species retained their sub- ıinant position.

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[5] Throughout the report, density of vegetation is expressed by the decimal system, 1.0 representing complete coverage.

ut quadrat.—The revegetation of the quadrat from which vegetation had been removed by cutting was very similar to t of the spaded quadrat, although the growths of *Elymus* *Artemisia* were more abundant and the invasion by *Empe- m* and *Stereocaulon* was less marked. Between the fifth and ninth years after cutting there was a decrease in the pro- tion of weed species, and sphagnum moss appeared and in- ısed rapidly. *Empetrum* showed little increase in the area ıpied, and *Stereocaulon* suffered a definite recession. The sity of the plant cover was estimated to be 0.8 at the end years.

heck quadrats.—During the 9-year period there was a definite nge in the vegetation on the check quadrats. *Stereocaulon,* dominant species when the quadrats were established, had rly disappeared when the latest observation was made. *Empe- m nigrum* spread to cover about 70 percent of the total area he quadrats. There was a general decline in the weed species the grasses showed little change.

onclusion.—The initial phase of vegetative succession in the ch-transition type appears to be an association of *Elymus llis, Epilobium latifolium,* and *Artemisia arctica,* with a few h minor weeds as *Achillea borealis, Mertensia maritima,* and *lopleurum gmelini.* These species are gradually replaced by asions of *Empetrum nigrum* and lichens, principally *Stereo- lon tomentosum.* With the development of a more luxuriant nt growth, *Stereocaulon* is replaced by the more tolerant sses, especially *Sphagnum.* The trend of the succession is ɔarently towards the association found on the surrounding ıdra.

t appears that the beach-transition type could be quite closely ızed without reducing its forage production, and it is probable ıt grazing would tend to prolong the *Elymus-Artemisia* stage the succession by retarding the development of the *Empetrum- reocaulon* phase.

The term "association" as used here has a slightly different meaning than is gen- ly given it in ecological literature. Because of the peculiar adaptations of Arctic ıts there does not seem to be the more or less characteristic association of species ïned to definite sites as is usually the case in more temperate climates. In the tic the same species are found over widely varying site conditions and the variations he plant cover, instead of being characterized by definite groups or associations of ies, are marked by variations in the relative abundance or proportions of the com- ı species.

PASTOLIK

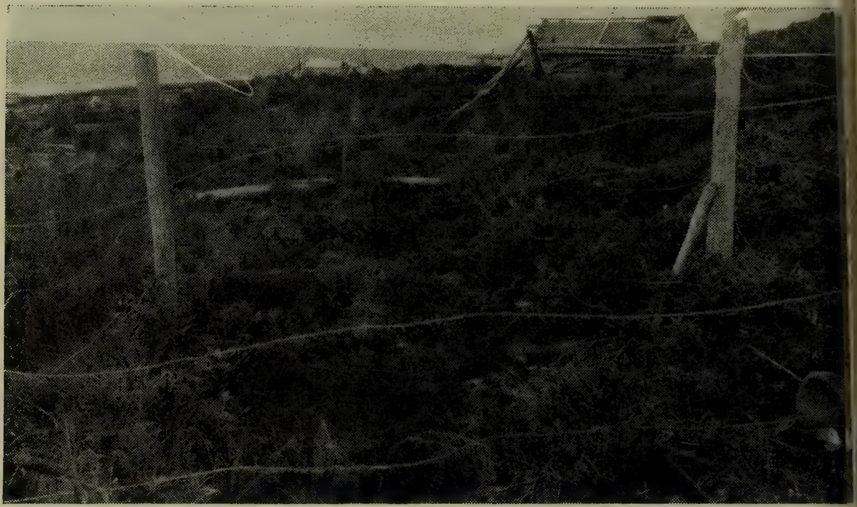

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Figure 3.—Beach-transition type exclosure at Pastolik. July 5, 1928.

The beach-transition type (fig. 3) studied at Pastolik near lat tude 63° N., longitude 163° W., is on a soil composed of smooth fine gravel and sand with a fair amount of humus. Soil moisture is plentiful throughout the growing season. There is a dense growth of vegetation, composed of approximately 20 percent *Arctagrostis*, 20 percent *Poa*, 20 percent *Agrostis*, 30 percent weeds, and 10 percent willows. The study was conducted in the same manner as that at Cape Etolin (p. 8).

Cut quadrat.—Four years after establishment the cut quadrat had a full cover of vegetation, composed of 50 percent grasses, 30 percent weeds, 10 percent willows, and 10 percent mosses. *Poa* made up 90 percent of the grasses. The rate of recovery manifested would indicate that the type has the ability to withstand moderately heavy grazing and still maintain a good stand of palatable forage.

Denuded quadrat.—The denuded quadrat made a much slower recovery. At the end of 4 years the plant density was 0.675, the vegetation comprising 50 percent mosses, 40 percent weeds, and 10 percent grasses. The mosses were very short and had no forage value. *Equisetum* and *Epilobium* formed the initial phase of the succession and were followed by the rapidly spreading mosses. Grasses were much slower in making their appearance. Further study is necessary in order to determine the trend and rate of succession.

Check quadrats.—The undisturbed or check quadrats also have changed in composition. Willows and mosses made substantial increases while grasses decreased. The percentage of weeds remained the same. It appears that, if undisturbed, the beach-transition type will develop into the browse-moss-weed association the adjoining tundra. It also appears that grazing tends to tard succession and that under use the grass-weed type would rsist.

SAND-DUNE TYPE

NUNIVAK ISLAND

Because of its limited occurrence, the sand-dune type is not of eat economic importance as reindeer range, but it is significant ologically, in that it affords opportunity to observe the develop- ent of vegetation on a primary area. The study of the vegeta- on on sand dunes, begun in 1927, was conducted at Cape Etolin n Nunivak Island. The experimental area was a fenced ex- osure (fig. 4) containing three 1-meter-square quadrats located

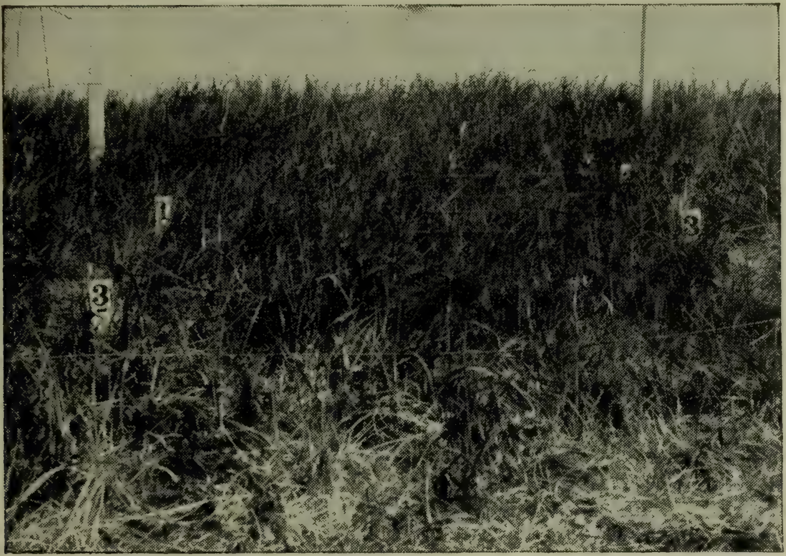

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Figure 4.—The study exclosure in the sand-dune type, Cape Etolin, Nunivak Island. July 4, 1929.

n the south or leeward side of a ridge of sand dunes at about 0 feet elevation. The soil is deep and is composed of fine sand ith very little humus. A small amount of wind-borne deposition still taking place. The soil is well drained but comparatively eavy precipitation during the summer furnished ample moisture or abundant plant growth.

The vegetation on this area is composed principally of grasses ith a small percentage of weeds and mosses. The grasses, ainly *Elymus mollis* and *Arctagrostis latifolia,* with smaller mounts of *Poa arctica* and *Festuca rubra,* constitute about 85 ercent of the total vegetation. The weeds *Epilobium latifolium, athyrus maritimus, Achillea borealis, Petasites* sp., *Solidago, conitum, Cerastium, Arenaria,* and *Cornus* make up about 8 percent of the plant cover. The remaining 7 percent consists small mosses. The plant cover has a density of 1.0.

Denuded quadrat.—One of the quadrats within this exclosu was denuded by spading up all the vegetation. Five years lat the vegetation had recovered sufficiently to make a cover densi of 0.12, composed of 70 percent grasses and 30 percent weeds. fine moss also was distributed evenly over the entire area. Ni years after denudation of the quadrat, the density of the pla cover was estimated to be 0.65, and the composition was 60 pe cent grasses, 20 percent weeds, and 20 percent sphagnum mos Apparently the grass-weed association is the primary stage the succession on this site. It is slow to reestablish itself follov ing removal or severe disturbance.

Cut quadrat.—A similar quadrat from which the vegetatic was removed by cutting it at the ground surface made a mo rapid recovery. After 5 years the grasses and weeds were four to have a density of 0.22. In addition there was an even cover fine mosses. Nine years after treatment the cover was estimate to have a density of 0.8. Grasses made up 50 percent of the veg tation, weeds 25 percent, and mosses and lichens 25 percent. A though the recovery was more rapid on the cut quadrat than c the spaded quadrat, the ratios of the components were esse tially the same.

Check quadrat.—Changes were noted in the composition of tl vegetation on the check quadrat, which was undisturbed durin the course of this study. *Elymus* decreased from dominanc until it made up only 10 percent of the cover, while *Arctagrost* increased until it dominated all other species. The fine grasse *Poa arctica* and *Festuca rubra* also made definite increases. Tl weeds showed little change either in species or abundance, bu *Sphagnum* increased from 7 percent to 20 percent of the tot cover.

During the years of protection afforded by the exclosure ther was a gradual accumulation of dead culms and leaves, formin a loose mulch over the ground, which apparently created favo able growing conditions for the mosses. The increase of mosse with their ability to form humus and retain moisture, helps t alter site conditions in favor of the lichen and browse species tha characterize the nearby tundra. It was noted at the latest exam ination of this type that *Elymus* was the dominant grass on th windward side of the dunes and that *Arctagrostis* prevailed on th leeward side.

Conclusion.—The reaction of the treated quadrats indicate that moderate utilization by grazing animals would tend to stabilize the sand-dune type by prolonging the grass-weed stage o the succession. Close utilization would open the cover and expos the soil to erosion by rain and wind. When undisturbed ther is a rather rapid development toward the association of specie characteristic of the adjacent tundra.

COAST-SANDSPIT GRASS-WEED TYPE

UNALAKLEET

The coast-sandspit grass-weed type occupies a narrow strip long the coast between the beach and the tundra. The soil is ell drained, gravelly loam with a fair amount of humus. Mois- re conditions, because of frequent summer rains, are favorable. he vegetation is a mixture of grasses, sedges, and weeds. The rasses *Poa* and *Elymus mollis* make up about 30 percent of the tal plant cover; sedges constitute 40 percent; and the weed pecies *Artemisia, Lathyrus, Polemonium, Conioselinum,* and *renaria* contribute the remaining 30 percent. The density of e cover is complete (1.0).

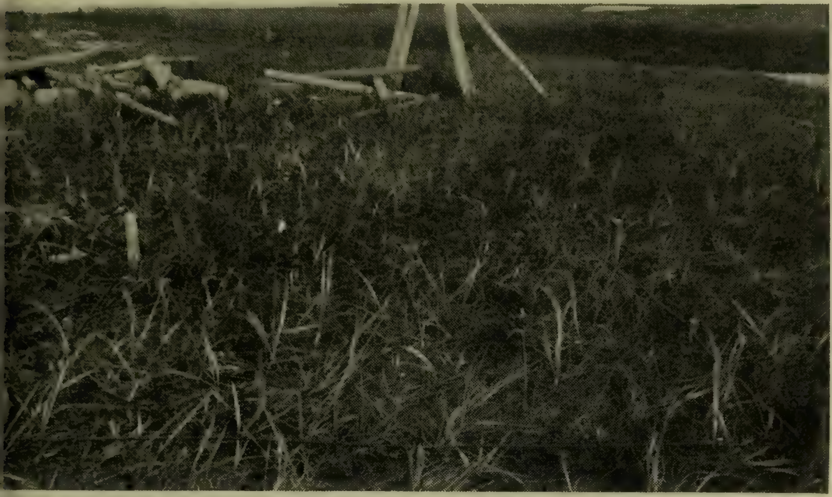

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Figure 5.—The grass-weed type exclosure on the coast sandspit, Unalakleet. August 11, 1927.

Denuded quadrat.—A fenced exclosure containing four 1-meter- quare quadrats was established in this type near Unalakleet in 927 (fig. 5). One of these quadrats was completely denuded by pading up and removing all the vegetation. The invasion of this rea by vegetation has been very slow. At the end of 4 years he invading plants had not attained a 0.1 density. The species ere the same as those found originally on the area and were in pproximately the same proportions. A small moss was spread- g evenly over the entire area.

Cut quadrat.—A similar quadrat from which the vegetation ad been removed by cutting it off at the ground surface made a uch more rapid recovery. At the end of 4 years the vegetative over had attained an estimated 0.85 density and was composed f 35 percent grasses, 30 percent sedges, 25 percent weeds, and 0 percent mosses. At that time there was evidence that the osses were being displaced by the other classes of vegetation.

Check quadrats.—There was no noticeable change in the vegetation on the check quadrats during the 4 years of observatio

Conclusion.—Although the study was not complete enough be conclusive, it indicated that the coast-sandspit grass-weed ty is comparatively stable, and that moderate grazing during th summer would not appreciably affect the forage production or th trend of the plant succession. Heavy grazing and tramplin such as would expose the ground surface would decrease th forage production considerably and alter the plant compositio the more palatable weeds and grasses would be eliminated an mosses would increase.

COAST-SANDSPIT LICHEN-BROWSE TYPE

UNALAKLEET

The coast-sandspit lichen-browse type is found on a slight ridg back from the beach. The soil is fine gravel and sand with a fai amount of humus. The vegetation is composed of lichens an browse with a few grasses. Despite frequent rains during th summer, the ground is rather dry and does not produce a luxuri ant stand of vegetation. The density is complete (1.0) but th stand is short, the browse species being decumbent and the lichen averaging not more than 4 inches in height.

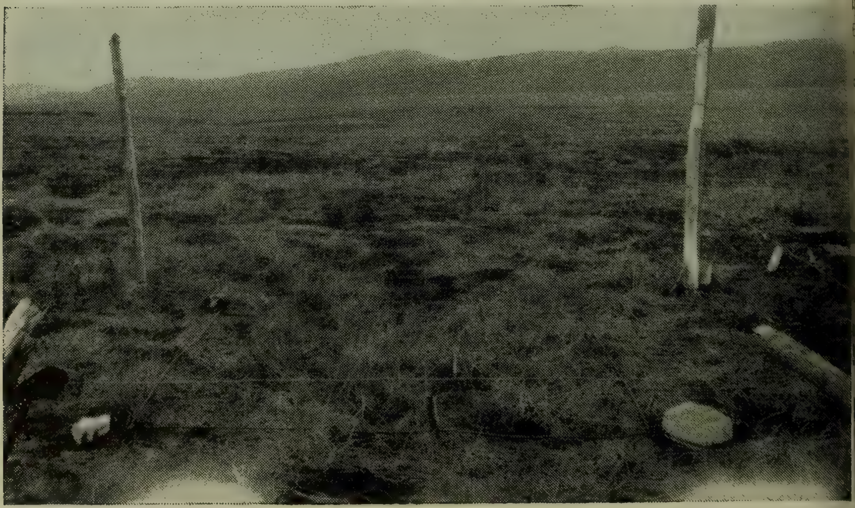

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Figure 6.—Lichen-browse type on a coast sandspit. Unalakleet. September 24, 1928.

A fenced exclosure containing four 1-meter-square quadrats was established on this type in 1922 just north of the town of Unalakleet, on Norton Sound, near latitude 64° N., longitude 161° W. (fig. 6). Observations were made until 1930, when the area was included in the airport of Unalakleet and the quadrats had to be abandoned.

Three-fourths-cut quadrat.—In order to study the effect of cropping on lichen growth, the vegetation on one of these quadrats was clipped so as to remove about three-fourths of the aboveground growth. Before the cutting, the area had a complete ground cover composed of about 60 percent lichens, 38 percent browse, and 2 percent grasses. The cutting was done in the spring while the ground was frozen. An examination made after the ground had thawed disclosed a weak lichen cover approximately half an inch high remaining.

After 9 years the vegetation on this area had a density of 0.95 and was composed of 25 percent grasses, 35 percent lichens, 25 percent browse, 10 percent mosses, and 5 percent weeds. The greater part of the lichen cover died during the year after the cutting but new growth was soon in evidence. The stand was opened, however, and this allowed the establishment of grasses and weeds. In 5 years the ground cover had a density of 0.95. In 9 years the lichens had attained a height of 1½ inches but were only slightly more than half as abundant as formerly. This would indicate that lichens are greatly affected by cropping, that they are very slow to recover, and are easily killed. Grazing tends to open the stand in this type and this permits the increase of grasses and weeds. The browse species were reduced by the cutting but they recovered more rapidly than did the lichens.

Denuded quadrat.—A similar quadrat, having a 1.0 density of cover composed of 75 percent lichens, 15 percent browse, and 10 percent grasses, was completely denuded in order to observe the recovery of the lichens. In 5 years the area was largely covered with grasses and browse to a density of 0.8. Lichens had come in rapidly but were of short growth. Nine years after establishment of the quadrat the vegetation had attained a 0.9 density and was estimated to be composed of 35 percent grasses, 25 percent browse, 30 percent lichens, 5 percent weeds, and 5 percent mosses. The lichens averaged about 1 inch in height.

In this instance the grasses were most aggressive in revegetating the area after the lichens were removed. Browse species also were stimulated by the opening up of the stand. Lichens were slow to reestablish themselves but were doing so gradually. The increased growth and spread of lichens was relentlessly crowding out and replacing the grasses, and eventually, during the course of years, would reclaim the area. The browse species tend to be more stable, but evidence indicates that finally they, too, give way to the lichens.

Picked quadrat.—A third quadrat in this group was originally covered with vegetation having a 1.0 density, and composed of 0 percent lichens, 25 percent grasses, and 5 percent browse. To study the effect of pawing and close winter cropping by reindeer on lichen growth, the lichens on this quadrat were picked by hand while the ground was frozen. The air-dry weight of these lichens averaged with that of the lichens removed from the denuded quadrat mentioned above indicated a forage production of 10,117 pounds to an acre. Examination of the area after the ground had thawed showed that no lichens were left. Five years after establishment the quadrat had a complete cover of vegetation estimated to be composed of 50 percent grasses, 25 percent browse, and 25 percent lichens. Nine years after its establishment the vegetation of the quadrat comprised about 40 percent grasses 27 percent browse, 25 percent lichens, 5 percent weeds, and 3 per cent mosses. The density was 1.0. Aside from the appearanc of weeds and mosses, the change in the vegetation between th fifth and the ninth years was very slight.

The recovery of this quadrat was more rapid than that of th denuded area but not as rapid as that of the partially cut o cropped quadrats. The proportions of plant species during th process of recovery, however, were in all cases essentially th same.

Check quadrat.—A fourth quadrat in this group was left undisturbed to serve as a check for comparison with the treated areas. Originally it had a complete cover of vegetation, with an estimated composition of 75 percent lichens, 15 percent grasses, and 10 percent browse. The lichen growth stood about 1 inch high above the frozen ground. After the ground had thawed it was noted that the lichens were brittle and had been trampled. Nine years later this quadrat had a cover of vegetation of 0.9 density that was estimated to be composed of 22 percent grasses, 22 percent lichens, 45 percent browse, 5 percent weeds, and 6 percent mosses. The trampling noted the year of establishment appears to have had an effect comparable to the other methods of treatment as the reactions were much the same. The lichen cover was greatly reduced and there was a corresponding increase in the grasses and browse. This emphasizes what has been observed many times, namely, that lichens are easily injured by trampling when in a dry and brittle state, and efforts should be made to protect them when they are in this condition; hence reindeer should be kept away from important lichen areas during the summer.

The recovery of the vegetation subsequent to extremely close cropping or denudation is much slower than that after partial cropping or cutting. While the quantity of forage removed from the partially cropped area was not so great as that from the denuded quadrat, the quicker rate of recovery would indicate an ultimately greater forage production over an extended period. Considering also the action of the forage cover in maintaining site conditions and preventing erosion, it is evident that moderate grazing under a deferred system of use would prove the most desirable practice in utilizing the coast-sandspit lichen-browse type.

COAST-TUNDRA SEDGE-BROWSE TYPE

EGAVIK

The coast-tundra sedge-browse type is found on practically all the lower ground near the coast, occupying the valley floors and poorly drained flats adjacent to the beach. This coastal strip comprises the greater part of the summer range for reindeer herds along the Bering Sea coast of Alaska.

This particular type occurs on a gentle northeast slope about half a mile from the beach. The soil is fine-textured loam with abundant humus. Soil moisture is abundant during the growing season owing to frequent rains and poor drainage. The vegetation is composed largely of *Eriophorum* and *Carex* with a fair proportion of browse species, as ground birch, Alaska tea, cranberry, *Empetrum,* and blueberry. Grazing by reindeer during the summer has been moderate for the past several years.

A fenced exclosure containing one 1-meter-square quadrat was established in 1927 for the purpose of studying the effect of protection on this type after moderate grazing. A similar quadrat for comparison was located nearby in the open where it was subject to grazing.

Five years of observations of these quadrats disclosed no significant change in the composition of the vegetation. There was an increase in forage production on the protected plot but not enough to be of special importance. Although the data are far too meager to be conclusive, it appears that this type is little affected by moderate summer grazing.

Tundra sedge-browse subtype.—This phase of the coast tundra is characterized by the predominance of *Carex,* with comparatively few "niggerheads" or *Eriophorum* clumps. Generally the vegetative cover is complete and is composed of approximately 5 percent *Carex,* 20 percent *Eriophorum,* and 35 percent browse. The browse species include *Empetrum,* ground birch, cranberry, blueberry, *Arctous,* Alaska tea, and salmonberry. Lichens and mosses appear occasionally but in negligible quantities. The soil is a deep, fine-textured loam with abundant humus, and although it is nearly saturated with moisture throughout the growing season, there is practically no erosion. The type is grazed moderately by reindeer during the summer.

To observe the effect on the vegetation of grazing and protection, an exclosure containing three 1-meter-square quadrats was established in 1927 and two additional quadrats were located in the open nearby.

Denuded quadrat.—One of the quadrats within the exclosure was denuded of vegetation by spading at the time it was established. Originally it had a complete cover composed of 45 percent *Carex,* 20 percent *Eriophorum,* 6 percent *Empetrum,* 5 percent ground birch, 4 percent cranberry, 8 percent blueberry, 5 percent *Arctous,* 5 percent Alaska tea, and 2 percent salmonberry. Five years later the vegetation on this quadrat had grown so as to attain a density of 0.65. The cover was made up of 60 percent *Carex* and *Eriophorum,* in about equal quantities, 20 percent *Polytrichum,* and 20 percent browse. A notable feature was the large number of seedlings of willow, *Empetrum,* Alaska tea, and low cranberry. The area was revegetated mainly by the same species that were found on the area originally and in much the same proportions. The single exception was the moss, *Polytrichum.* These plants made their appearance rapidly on exposed soil in a moist site. The seedlings of the sedges and browse species apparently had little difficulty, however, in establishing themselves in lightly covered, mossy areas.

Check quadrats.—The other two quadrats within the exclosure were left undisturbed to serve for comparison with the denuded quadrat and to note the effect on the vegetation of protection from grazing. At the time the quadrats were established, the vegetation on them had a complete density (1.0) and was composed of 65 percent *Carex* and *Eriophorum,* and 35 percent browse. After 5 years the density of the vegetative cover was unchanged, and the plant composition was estimated to be 80 to 85 percent *Carex* and *Eriophorum* and 15 to 20 percent browse Protection from grazing apparently promoted the growth and spread of *Carex* and *Eriophorum* over that of the browse species at least during the first 5 years.

Denuded open quadrat.—One of the quadrats outside the exclosure was denuded by spading off the vegetation. Before the removal of the plant cover its density was complete (1.0), the vegetation consisting of 55 percent browse and 45 percent *Carex* Five years later the cover on this area was estimated to be of 0.5 density and was composed of 50 percent mosses and 50 percent sedges and browse. Lichens were first noted during the fifth year when 5 small groups were found.

The recovery of the denuded area that was exposed to grazing was much slower than that of the protected plot. Not only was there less vegetation on the exposed plot, but also a much larger proportion of unpalatable mosses. The sedges and browse species did not exhibit the thrift and vigor displayed by the plants in the protected area. This would indicate that even moderate grazing tends to retard the revegetation of denuded or badly depleted areas.

Check open quadrat.—The vegetation on the undisturbed quadrat established outside the exclosure had an estimated density of 1.0 and was composed of 55 percent browse and 45 percent *Carex.* During the 5 years that this area was under observation the vegetation changed in composition to 40 percent sedges, 50 percent browse, 8 percent mosses, and 2 percent lichens. The density remained unchanged. Although these data are not sufficient to warrant definite conclusions, it appears that under grazing this type is gradually changing from a sedge-browse type to a predominantly browse type. The reverse occurred in the protected plot. Summer grazing apparently tends to reduce the quantity of sedges and thus permit increased growth of the browse species. Just what effect this will have on the ultimate carrying capacity of the type is yet to be determined.

TUNDRA-LICHEN TYPE

The tundra-lichen type is of great economic importance to the reindeer industry. It is found extensively over the lower tundra areas along the Bering Sea and Arctic coasts and constitutes much of the fall and early winter range of the reindeer.

NUNIVAK ISLAND

An exclosure containing four 1-meter-square quadrats was established in the tundra-lichen type near Cape Etolin, on Nunivak Island, in 1922. The site chosen was at about 100-feet elevation n a gentle northwest slope (fig. 7). The soil is deep, moist loam vith much humus. Precipitation is abundant throughout the ummer months. Heavy fogs occur frequently, and the moisture hus supplied is extremely favorable to the growth of lichens. hese averaged 6 inches in height and made up about 80 percent f the total vegetative cover. Sedges and browse species comosed the remainder of the vegetation.

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igure 7.—The exclosure in the lichen tundra 7 years after establishment, Nunivak Island. July 5, 1929.

Picked quadrat.—On one of the quadrats the lichens were icked by hand, very little of the roots being left with the base tand of 25 percent *Carex, Dicranum, Ledum,* and *Empetrum,* and scattering of willow, blueberry, cranberry, and salmonberry. he lichens removed had an air-dry weight of 3 pounds 2 ounces; his indicated a forage yield of 12,646 pounds to an acre. Vegeation gradually reclaimed the area, a cover of 0.9 density being ttained in the tenth year after the lichens had been picked and complete cover between the tenth and fourteenth years. Foureen years after treatment of the quadrat, the lichens averaged inches in height and made up 55 percent of the ground cover. he remainder of the vegetation consisted of 20 percent *Carex* nd 25 percent browse, including *Ledum, Empetrum,* willow, salmnberry, and cranberry.

Picked and trampled quadrat.—From a second quadrat, very imilar to the first, the lichens were removed by picking, after vhich the ground was so treated as to simulate the results of ntensive grazing and trampling by reindeer. A cover composed f *Carex* and *Dicranum* of about 0.1 density remained on the round after treatment. During the next 5 years the revegetaion consisted largely of sedges with the mosses *Polytrichum* and *icranum* making up about one-tenth of the cover. In the folowing years other species gradually appeared, including *Ledum,* salmonberry, cranberry, willow, *Empetrum,* and such lichens a *Cladonia* and *Cetraria.* Fourteen years after establishment o the quadrat the vegetative cover was of 0.95 density and wa composed of approximately 30 percent sedges, 15 percent browse 20 percent lichens, and 35 percent mosses. The lichens were mos abundant along the edges of the quadrat and averaged abou 1½ inches in height.

The reaction of the vegetation to picking and trampling indicates that trampling is an important factor in the rate of recovery in this type. It would appear that moderate to ligh utilization and a short rotation would cause less disturbance an contribute to greater forage production than intensive grazin with a long rotation period.

Half-cut quadrat.—The third quadrat in this group, which ha a complete cover of vegetation (density 1.0) made up of 90 percent lichens and 10 percent sedges, mosses, and browse species was clipped so as to remove the top half, to simulate light grazing. The air-dry weight of the lichens removed was 2 pound 14 ounces, which indicated a forage yield of 11,635 pounds to a acre. Revegetation was at first largely by sedges and mosse but later by browse species, including ground birch, *Ledum,* an salmonberry. The greater part of the lichens apparently wer killed by the clipping, but new growth appeared, mainly by invasion from the edges. Fourteen years after treatment th vegetative cover was estimated to have a density of 0.9, and t be composed of 20 percent sedges, 40 percent lichens, 16 percen browse (principally ground birch), and 24 percent mosses. Th lichens were most abundant along the edges of the quadrat an averaged 2 inches in height.

Cutting appeared to retard the growth of lichens more tha did picking, but not so much as did the picking and tramplin treatment. Lichens are delicate, and the removal of a ver large proportion of the plants seems to be fatal to the liche range, at least during certain seasons. The vascular plants ca withstand a greater degree of disturbance and recover muc more rapidly.

Check quadrat.—The fourth quadrat in the group had a complete cover of vegetation (density 1.0) made up of 80 percent lichens and 20 percent sedges, mosses, and browse species. It was left undisturbed for comparison with the treated quadrats. In the first 5 years a definite decrease in lichens and a corresponding increase in sedges were noted. This was likely due to inadvertent trampling when the quadrat was laid out or to disturbance during subsequent chartings. It has been forcibly demonstrated during the course of these studies that when dry, lichens are brittle and very susceptible to injury. During the following years the vegetative development closely corresponded with that on the picked quadrat except that on the check quadrat the lichens were of larger growth and were more evenly distributed. Fourteen years after establishment of the quadrat the vegetative cover was complete and was composed of 35 percent sedges, 5 percent Alaska tea and cranberry, 50 percent lichens, and 10 percent mosses. The lichens averaged $3\frac{1}{2}$ inches in height.

Summary.—From the history of these quadrats it is apparent that lichen range is quick to react to any disturbance. The length of time required for recovery is directly proportional to the degree of disturbance. Revegetation occurs both by invasion from established plants in surrounding areas and by the establishment of new individuals within the area. The reestablishment of lichens is very slow. The picked quadrat made the most rapid and satisfactory recovery, and as this treatment closely simulates the grazing action of reindeer when they are loosely herded, it would seem that open herding, once over, on this type of range and then allowing a lapse of 6 to 8 years for recovery would be the most conservative manner of utilizing it. It appears that trampling has a greater damaging effect upon lichens than has actual grazing or removal of plant parts; open herding would minimize this damage.

The use of 1-meter-square quadrats is important in the study of reindeer ranges in that it has a relation to the feeding habits of the animals. Preferably they graze for a short time on a small area, then move on to another, even though there may remain much forage on the area they leave. This habit results in lighter utilization and permits a shorter period of rotation than would be possible if the reindeer grazed evenly and closely as they moved over the range.

The study of lichen ranges and their reaction to grazing is extremely important. The management of winter ranges, which are largely lichen areas, so as to keep them on a sustained yield basis, is fundamental, as without adequate winter range there can be no reindeer industry. Summer ranges, while equally important, are much less exacting in their management requirements and recover more rapidly after use.

PASTOLIK

The tundra-lichen type at Pastolik is very similar to that on Nunivak Island. It occupies the low rolling hills just back from the beach. The vegetation may be roughly grouped as 75 percent lichens, 15 percent sedges, and 10 percent browse plants. The browse species comprise ground birch, *Ledum,* salmonberry, *Empetrum,* and cranberry. The soil is deep, moist loam with an abundant supply of humus.

An exclosure (fig. 8) containing four 1-meter-square quadrats was established on this type in 1922. The last observations were made in 1931.

Cut quadrat.—One of these quadrats was treated by cutting off the top half of the lichen cover. The vegetation, which was of full density (1.0), was composed of 75 percent lichens, 15 percent sedges, and 10 percent browse. Two years after establishment of the quadrat a very marked invasion of vascular plants was noted. After 9 years the density of the vegetation was again complete, the plant composition being estimated as 65 percent sedges, 5 percent browse, 10 percent mosses, and 20

percent lichens. Disturbance of the lichen cover gave a sha
impetus to the growth of *Eriophorum* and *Carex,* these two ge
era taking over practically the whole area. If the quadrat
left without further disturbance, the *Eriophorum* and *Car*
doubtless will gradually be replaced by lichens and mosse
Browse species did not show any great response to the trea
ment. Decline of *Eriophorum* was evident in its lack of vigo
When examined in 1931 the *Eriophorum* outside the exclosu

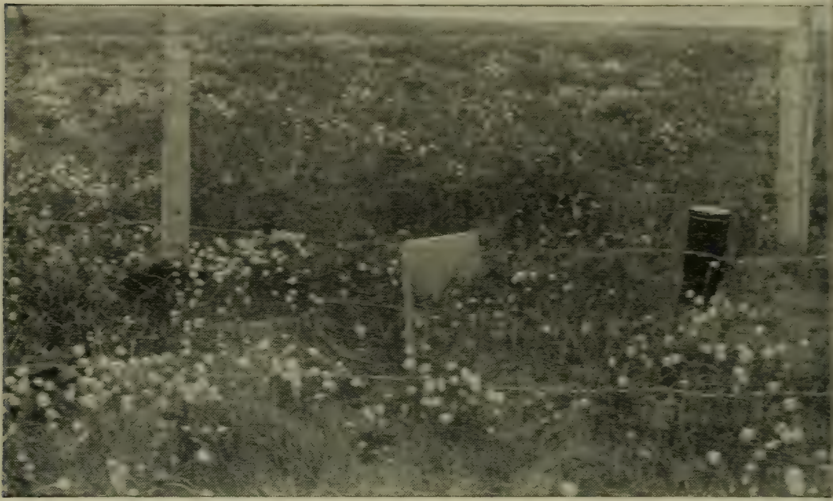

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Figure 8.—The tundra-lichen exclosure at Pastolik 6 years after its establishment. July 4, 1928.

was in full bloom and very abundant, while on the quadrat nc
a flower stalk was observed.

Denuded quadrat.—The second quadrat in the exclosure, ver
similar to the first in density and composition, was denuded b
cutting the vegetation at the ground surface and then tramplin
the area. Four years later little lichen growth had appearec
the area being entirely taken by *Eriophorum.* After 9 years th
vegetative cover was complete (density 1.0) and had an est
mated composition of 80 percent sedges, 5 percent lichens, 1
percent mosses, and 5 percent browse.

After the quadrat was denuded there was an almost immediat
establishment of a full vegetative cover of *Eriophorum.* Nin
years of protection found the *Eriophorum* beginning to decline
as was evidenced by the quantity of dead leaves and the lack o
vigor in producing flower stalks. Sphagnum mosses and lichen
were increasing underneath the mat of *Eriophorum* leaves bu
their progress was slow.

Picked quadrat.—The third quadrat in this series was ver
similar to the others and from it the lichens were picked b
hand; a 25-percent stand of sphagnum moss, sedges, and brows
remained. The air-dry weight of the lichens removed from th
area indicated a production of 22,764 pounds to an acre. A

heavy invasion of *Eriophorum* followed the treatment, but after 4 years there was noted an abundant reproduction of lichens from 1 to 2 inches in height. After 9 years the vegetation was of complete density (1.0) and was estimated to be composed of 65 percent sedges, 15 percent lichens, 10 percent browse, and 10 percent mosses. *Eriophorum* declined rapidly during the last 4 years of the period. The recovery of the half-cut and the picked quadrats was very nearly equal, indicating that the treatments were practically identical in effect.

Check quadrat.—The check quadrat in this group was very similar to others at the time of establishment but 4 years later, in 1926, it was observed that part of the plants had been killed by trampling. The last examination, made in 1931, showed that the area had a complete vegetative cover composed of 35 percent sedges, 35 percent lichens, 20 percent browse, and 10 percent mosses. The lichens appeared to have made considerable recovery after their being trampled prior to 1926. *Eriophorum* was dying out, and all 4 quadrats were covered with a 6-inch layer of interwoven dead stems and leaves of this plant. Underneath this mat was a good stand of lichens, largely *Cladonia,* and of sphagnum moss. Browse species, with the exception of salmonberry, appeared thrifty.

Summary.—Disturbance of the lichen cover on the moist tundra-lichen type is followed by an almost immediate invasion of vascular plants, chiefly cotton-sedge (*Eriophorum*), that is in direct proportion to the amount of disturbance. Trampling of this type, especially at a time when the lichens are dry and brittle, causes fully as much, if not more, damage than does actual grazing.

UNALAKLEET

An exclosure containing four 1-meter-square quadrats for the study of the tundra-lichen type was established in 1922 on a spur ridge about 3 miles up the Unalakleet River from its mouth. The site chosen was about 150 feet in elevation, nearly level, with a southwest exposure. The soil is a fairly deep loam with abundant humus. Although the soil is well drained, its moisture content is sufficiently high to support a good stand of vegetation (fig. 9). This type is drier than the preceding two tundra-lichen types discussed and contains smaller quantities of sedges and niggerheads. It is more characteristic of the tundra on the hills back from the coast.

Scraped quadrat.—These quadrats were established early in spring while the ground was frozen and there was a light cover of snow. The snow being brushed from the first quadrat, there was revealed a full cover of vegetation composed of 80 percent ichens, 10 percent sedges, and 10 percent browse. The lichens were semi-dry and somewhat brittle and stood about 2 inches above the frozen ground. The vegetation was scraped clean with a hand rake to the frozen ground surface, the lichen base being left intact and protected by the frozen ground and snow. The ichens removed from the area, when air-dry, indicated a forage yield of 5,140 pounds to an acre. Later, after the ground ha thawed, it was found that the quadrat had a remaining cove of lichens ½ to 1 inch in height. In September of the sam year it was determined that half of the vegetation on the quad rat was dead. The next year it was observed that new growt was forming on some of the cut lichen stubs. This was lik coppice growth, with the new branches $\frac{1}{16}$ to ⅛ inch in length It was estimated at that time that two-thirds of the origina vegetation was dead. After 10 years the area had a vegetativ

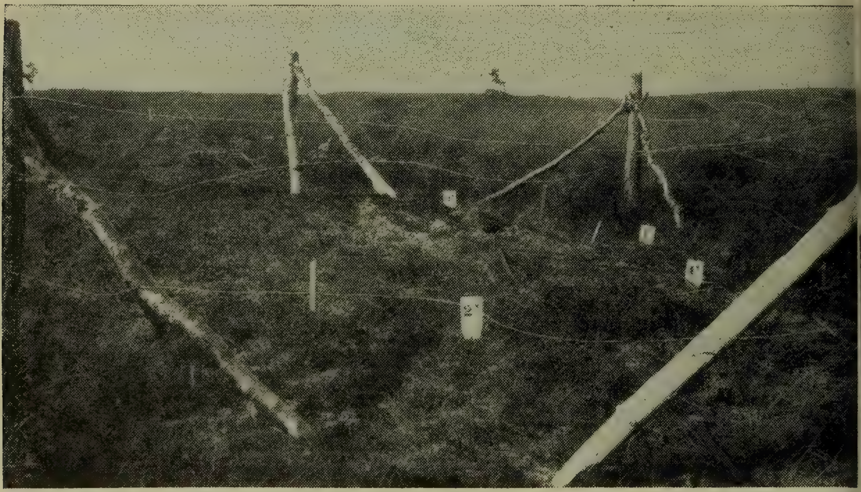

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Figure 9.—The exclosure in the tundra-lichen type. Unalakleet. August 24, 1929.

cover estimated at 0.95 density, composed of 50 percent lichens, 30 percent browse, 15 percent sedges and grasses, and 5 percent mosses. The lichens averaged 2½ inches in height.

Lichens thus have the power to resume growth after a part of the plant has been removed, although frequently it appears that such treatment is fatal. In this instance two-thirds of the plants were killed. Recovery was slow, and in 10 years the lichens had regained only slightly more than half of their former abundance and height growth. Browse species were stimulated by the opening of the lichen stand, but sedges and mosses made little response.

Clipped quadrat.—The second quadrat in this exclosure was very similar in appearance to the first when established. The vegetation was clipped to take off about the top half of the forage exposed above the frozen ground. The lichens removed from the quadrat had an air-dry weight of 0.65 pounds, which indicated a yield of 2,630 pounds to an acre. After the ground had thawed there was a remaining lichen cover 1 to 2 inches in height. Later it was determined that on this quadrat, as on the first, half of the vegetation had been killed. After 10 years the density of the vegetation was complete (1.0). The vegetative cover was estimated to be composed of 50 percent lichens, 45 percent browse, and 5 percent grasses and sedges. The lichens averaged 3 inches in height. Although cutting apparently did not affect the vegetation as much as did scraping, yet it caused great reduction in the lichen stand. It will require several more years for the lichens to regain completely their former abundance and volume. The immediate result of reducing the lichens was to stimulate the growth of browse. Sedges did not seem to be materially affected by the treatment.

Denuded quadrat.—The third quadrat, similar to the others originally, was scraped clean to the frozen ground surface at the time of establishment. Later when the ground had thawed there remained a cover of lichens $1\frac{1}{2}$ to 2 inches in height. This also was removed by scraping, the area being thus completely denuded. The following year considerable lichen reproduction was found, a growth of $\frac{1}{16}$ to $\frac{1}{8}$ of an inch being noted on old stumps. The lichens observed at that time were *Cladonia rangiferina, C. sylvatica, C. sylvatica sylvestris, Cetraria cucullata, C. islandica,* and *Stereocaulon tomentosum.* Ten years after establishment the quadrat was covered with vegetation to an estimated density of 0.85 composed of approximately 35 percent lichens, 40 percent browse, 15 percent sedges and grasses, and 10 percent mosses. The lichens averaged about 1 inch in height.

This denuded area made nearly as rapid recovery as did the half-cut and the scraped quadrats. The original species revegetated it, but their proportions were changed. On this drier site the increase of *Carex* and *Eriophorum* following denudation of the area was negligible. On the other hand, the browse species were noticeably stimulated. Lichens, also, made a good recovery, especially where the ground surface remained sufficiently clear.

Check quadrat.—The fourth, or check, quadrat in this type was left undisturbed at the time of establishment. The vegetation formed a complete cover and was estimated to be composed of 80 percent lichens, 10 percent browse, and 10 percent sedges. The lichens averaged between 2 and 3 inches in height above the frozen surface, and later, after the ground had thawed, they measured between 3 and 4 inches in height. The quadrat must have been trampled at the time of establishment or during later examinations, because 5 years after its establishment it was estimated that about half of the lichen stand was dead. At that time the cover was composed of 50 percent lichens, 40 percent browse, and 10 percent sedges. In 1932, 10 years after establishment of the quadrat, the plant composition was estimated to be still the same.

Because of disturbance the quadrat failed to fulfill its purpose but instead yielded further information on the reaction of lichens to trampling. The stand in this case was reduced by approximately 40 percent, presumably from trampling, and did not make any appreciable recovery during the last 5 years of the investigations. This again clearly demonstrates the fragile and delicate nature of these plants and emphasizes the necessity of guarding lichen areas against trampling or use during the summer.

Summary.—On the dry tundra-lichen type a reduction in vegetative cover through grazing, as typified by the treated quadrats, is followed by accelerated growth of the browse species. *Carex* and *Eriophorum* show little response to the opportunity for expansion. Lichens recover as readily, if not more so, as on more moist sites, because the ground is left unoccupied by competitors for a longer period. On this type conservative use would not open the ground cover sufficiently to allow damage from erosion due to spring runoff and summer rains, and would permit the use of a fairly short rotation. Intense use, sufficient partially to denude, would cause a severe loss of forage through trampling, would open the vegetative cover and produce an erosion hazard, and finally would necessitate deferring use of the area for a period of 20 to 30 years to allow the vegetation to recover sufficiently to be grazed again.

WET-TUNDRA SEDGE-LICHEN TYPE

NUNIVAK ISLAND

The wet-tundra sedge-lichen type is a typical lowland tundra type and is found extensively along the Alaska coast. It is more boglike than the "niggerhead" tundra, although most of the species found there, except the sphagnum mosses, are also present in the "niggerhead" type. In the wet-tundra sedge-lichen type the soil is deep, spongy, and peatlike. It is saturated with moisture throughout the growing season and drainage is poor.

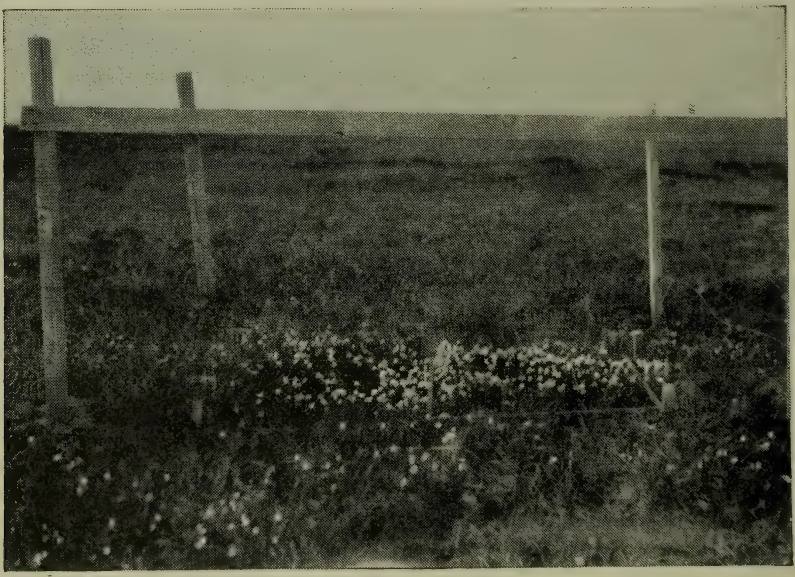
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Figure 10.—Sedge-lichen vegetation in the wet-tundra type, Nunivak Island. July 4, 1929.

The vegetation is dominated by the sedges, with lichens (*Cladonia* and *Nephroma*) present in smaller quantities. The browse species are *Ledum,* prostrate willows, ground birch, *Empetrum,* and cranberry.

Study of this type was begun in 1927, when an exclosure was erected about a mile south of the native village at Cape Etolin on Nunivak Island. The site chosen was nearly level and at about 70 feet elevation. Three 1-meter-square quadrats were established within the exclosure for the purpose of determining the effect of grazing, denudation, and trampling on the sedge-lichen vegetation (fig. 10).

Cut quadrat.—The first of these quadrats had a full cover of vegetation estimated to be composed of 45 percent sedges, 32 percent lichens, 12 percent browse species, and 11 percent mosses. This was removed by cutting it at the ground surface with a sharp knife.

A full cover of vegetation was reestablished the third year after the cutting, with *Eriophorum* making up 75 percent of the stand. Mosses were estimated to compose 15 percent and lichens the remaining 10 percent of the growth. Nine years after cutting the vegetative cover consisted principally of sedges, *Carex* forming 40 percent and *Eriophorum* 60 percent. A vigorous growth of sphagnum moss was found underneath the accumulation of dead sedge leaves.

Spaded quadrat.—The second quadrat was similar to the first, having a complete cover of vegetation made up of 45 percent sedges, 31 percent lichens, 12 percent browse species, and 12 percent mosses. The plants, including their roots, were removed by spading. Revegetation occurred rather slowly, a complete cover not being established after a lapse of 9 years. *Eriophorum* was the principal invader, followed by *Carex, Sphagnum,* and willow. When the quadrat was last examined, in 1936, the density of the vegetative cover was estimated to be 0.95. *Eriophorum* composed 40 percent of the stand, *Carex* 35 percent, sphagnum mosses 20 percent, and willows 5 percent. The willows apparently crept in by layering from plants in the check quadrat.

Check quadrat.—This undisturbed quadrat had a complete cover of vegetation made up of 50 percent sedges, 30 percent lichens, 15 percent browse species, and 5 percent mosses. During the period of observation some changes occurred in the vegetative cover. A gradual decrease in lichens and a corresponding increase in sedges and willows were recorded. At the end of 9 years the cover was complete and was made up of 70 percent sedges (*Carex* and *Eriophorum* in about equal quantities), 22 percent browse, mostly willow, and 8 percent lichens and mosses.

Many runways of lemmings were found underneath the accumulation of dead sedge leaves. It is possible that these rodents caused some of the change in vegetation, but observations on this point have not been sufficient to be conclusive.

Summary.—The length of time required for vegetation in the wet tundra type to recover after disturbance seems to be directly proportional to the degree of disturbance. *Eriophorum callithrix* is the principal species to appear following disturbance and may be considered a reliable indicator of overgrazing in this type.

WET-TUNDRA SEDGE TYPE

UNALAKLEET

The wet-tundra sedge type is of rather common occurrence on the low tundra used as summer range for reindeer. This part of the tundra is dotted with small, shallow, fresh-water ponds and lakes, around the margins of which sedges frequently occur in pure stands. The soil is fine and deep with a high humus content. These areas are usually flooded during the spring, and the soil remains saturated throughout the summer.

The site chosen for the study of this type was 200 yards back from the margin of a small fresh-water lake, and about a mile north of the reindeer corrals at Unalakleet. A fenced exclosure surrounding three 1-meter-square quadrats was erected in 1927 to study the effect of grazing and denudation on this wet-tundra type. The exclosure (fig. 11) was located within the driveway leading to the reindeer corrals and, in 1932, the Lapps removed the exclosure fence and allowed the area to be severely trampled by the reindeer.

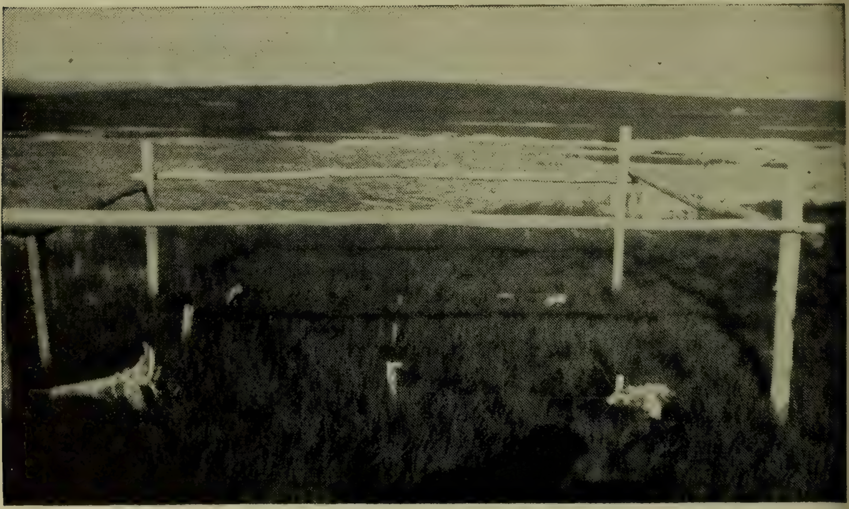

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Figure 11.—The study area in the wet tundra. Unalakleet. September 22, 1928.

Cut quadrat.—When the quadrat was established the vegetation had a density of 0.4 and was made up of a very even stand of sedges and about 10 percent mosses. The area was denuded by cutting the vegetation at the ground surface. The following year the plot was occupied by a stand of sedges having a density of about 0.35. At the end of 5 years, and after being trampled by reindeer during the summer of the fifth year, the vegetation was composed of a pure stand of sedges of 0.5 density.

Spaded quadrat.—The second quadrat in this group was similar in appearance to the first, when established. The vegetation n the area was completely removed by spading it up. At the nd of the first year there was a pure stand of sedges with a density of 0.2. After 4 years the plant density had increased o 0.6, the vegetation being composed of 90 percent *Carex* and 0 percent fine grasses of undetermined species but thought to be bluegrass. At the end of the fifth year, after being trampled by reindeer, the vegetation was a pure stand of *Carex* of 0.5 ensity.

Check quadrat.—Originally the check quadrat was very similar to the others in the group. It had a vegetative cover of approximately 0.4 density composed of 90 percent *Carex* and 10 percent mosses. It was left undisturbed for comparison with he other quadrats and to observe the effect of protection. After years the vegetation was made up of 90 percent *Carex* and 10 percent fine grasses. The density was estimated to be 0.65. A ery small moss growing between the sedge clumps, if included, would bring the density up to 0.8. During the fifth year, after being trampled by reindeer, the vegetation was again reduced o 0.5 density and was composed of a pure stand of *Carex.*

Summary.—On this wet-tundra type the vegetation readily reovered after denudation of the area, an almost pure stand of *Carex* coming in. Under protection density increased and an invasion of fine grasses was noted. One season without protection, however, was sufficient to undo the progress of 4 years and render he area substantially the same as when the studies were started. t would be interesting to continue the study to determine the progress and effect of the grass invasion.

GRASS-BROWSE TYPE

NUNIVAK ISLAND

The grass-browse type is of rather limited occurrence and of minor importance compared with the types that make up the greater part of the reindeer ranges. It is confined to shallow gulches and along stream courses and does not extend far to either side. The limiting factors are probably soil and soil moisture, and it is likely that drifting snow exerts an influence. The soil is fine, deep loam, very rich in humus. It is wet, if not saturated, during most of the growing season. The vegetation is predominantly willows and grasses. Other plants found in lesser abundance in this habitat are *Carex, Ranunculus, Potentilla, Petasites, Polemonium, Equisetum,* and *Epilobium. Bryum* and a few lichens, largely species of *Cladonia,* are found occasionally underneath the other plants.

A fenced exclosure containing three 1-meter-square quadrats for studying this type was erected in 1927 about 1½ miles south of the native village at Cape Etolin on Nunivak Island (fig. 12).

Spaded quadrat.—The first quadrat in this group was completely covered with a rank growth of *Arctagrostis* and willows. The willows shaded about 70 percent of the area. This vegetation was completely removed by spading. Two years later thi quadrat again supported a full stand of vegetation. It was composed, however, of 65 percent mosses, 15 percent *Equisetum,* 1 percent grasses, and 5 percent weeds (*Petasites, Viola,* and *Artemisia*). During the next 7 years there was a gradual decrease in mosses and an increase in the number and quantities of weeds Willows became reestablished and increased slowly. Grasses decreased in the amount of area covered. The final charting made 9 years after spading revealed a cover density of 0.6, the vegetation being composed of 65 percent mosses, 8 percent *Arctagrostis,* 9 percent willow and salmonberry, and 18 percent weeds, including *Artemisia, Petasites, Epilobium, Viola,* and *Polemonium.*

Cut quadrat.—The second quadrat in this group was originally similar to the spaded quadrat, having a full cover of willows and *Arctagrostis.* The vegetation was removed by cutting it at the ground surface and then trampling it. Two years later there was a full cover of vegetation made up of 85 percent grasses, 8 percent mosses, and 7 percent weeds. The vegetation was again removed by cutting. The following year the plant cover had a density of 0.8 and was composed of 38 percent grasses, 50 percent mosses, and 12 percent weeds. During the next 6 years there was a gradual increase in the number of species and quantities of weeds and browse and a decrease in the mosses. The last charting recorded a cover of 0.9 density made up of 30 percent grasses, 30 percent weeds, 30 percent mosses, and 10 percent browse species. *Petasites, Equisetum, Coelopleurum,* and *Artemisia* were the dominant weeds.

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Figure 12.—The site of the study of the grass-browse type on Nunivak Island. June 27, 1927.

Check quadrat.—The check quadrat was similar in density and composition to the treated quadrats when established. Subseuent observations over the 9-year period revealed a gradual deline in the grasses and mosses and a corresponding increase in he quantity of weeds. The final charting recorded a vegetative over of 0.9 density composed of 25 percent *Arctagrostis,* 48 perent weeds, 17 percent mosses and lichens, and 10 percent thimbleerry (*Rubus arcticus*). The dominant weeds were *Artemisia, oelopleurum, Honkeneya,* and *Equisetum.*

Summary.—The vegetative cover was rapidly restored to areas in the grass-browse type after denudation. The original *Arctarostis*-willow association was first replaced by a moss-*Equiseum-Arctagrostis* cover. During the following years the progress f succession was marked by a gradual increase in weed species nd a decline in the mosses. Significant changes in the composiion of the vegetation on the check quadrat were recorded but re not as yet fully understood. These changes may have resulted rom the protection afforded by the exclosure or they may be sucessional changes by which the type is adjusting itself to the abitat. It appears that the grass-browse type would bear rather ntensive grazing without impairing its productivity.

HEATH TYPE

NUNIVAK ISLAND

The heath type is a typical subtype in the better drained browse undra. The soil is deep, with a top layer of humus that is peatke in character. The subsoil is fine, gray, and of volcanic origin. oil moisture is plentiful during the growing season. *Empetrum igrum* is the dominant species, and associated with it are *Arctous lpina,* cranberry, willows, and salmonberry, as well as sphagnum oss and a few lichens.

The site chosen for the study of this type was about 2 miles outh of the native village at Cape Etolin on Nunivak Island on gentle northerly slope at about 100-feet elevation. A fenced xclosure surrounding three 1-meter-square quadrats was erected here in 1927 (fig. 13).

Spaded quadrat.—When established this quadrat was covered ompletely with vegetation made up of 80 percent *Empetrum* nd 20 percent willow, cranberry, salmonberry, *Arctous alpina, arex, Cetraria islandica, Cladonia,* and mosses. The plant cover as removed by spading. In 2 years a vegetative cover of 0.8 ensity was reestablished. It was made up of 70 percent mosses, 6 percent weeds (*Equisetum* and *Petasites*), and 4 percent rasses. During the next 7 years there was a slow increase in he number of weed and browse species. The last charting reealed a cover of 0.6 density composed of 7 percent grasses, 13 ercent weeds, 15 percent browse species, and 65 percent mosses. he weeds were dominated by *Equisetum* and *Petasites,* but *ornus, Artemisia, Arnica,* and *Honkeneya* also were present. he browse species were about equally represented by willows, *mpetrum,* cranberry, salmonberry, and thimbleberry.

Cut quadrat.—The second quadrat in this group had a complete over of vegetation composed of 85 percent *Empetrum nigrum,* with scattering willows, *Petasites, Arctous,* cranberry, *Care* and lichens making up the remaining 15 percent. This cover wa removed by cutting it at the ground surface. Two years after th cutting the vegetation had an estimated density of 0.3 and wa composed of 10 percent grasses, 20 percent browse species, 6 percent weeds, and 10 percent mosses. Five years after the cutting the density of the cover was 0.9. Mosses were growing over the entire area and salmonberry plants were too numerous to chart individually. Many small lichens ⅛ inch high were noted. After 9 years the salmonberry plants had entirely disappeared. The vegetation had a density of 0.9 and was made up of 40 percent browse species, 35 percent mosses and lichens, 22 percent weeds, and 3 percent grasses and sedges. *Empetrum* was the dominant browse species, but cranberry, *Arctous,* willows, and *Ledum* also were represented. Weed species were about equally represented by *Petasites, Polemonium, Arnica, Honkeneya, Artemisia, Coelopleurum, Gentiana,* and *Aconitum.* The browse species appeared vigorous and spreading.

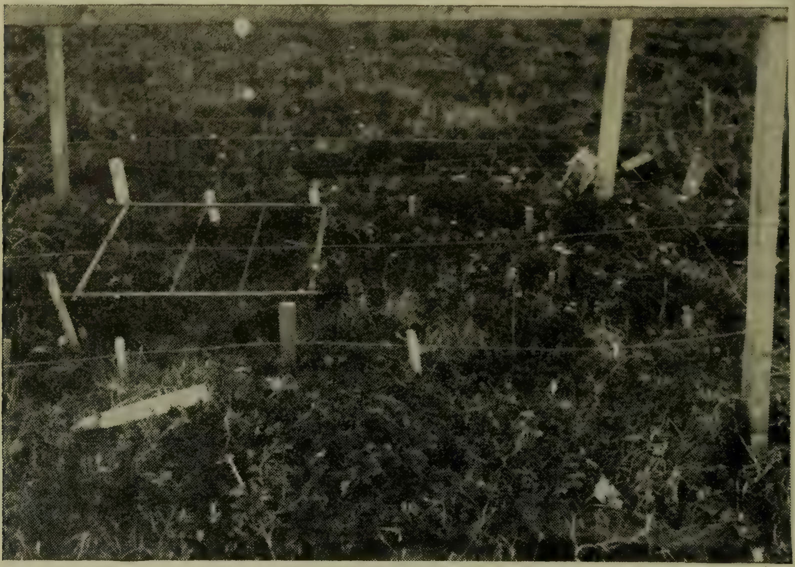

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Figure 13.—The heath type exclosure on Nunivak Island. July 5, 1929.

Check quadrat.—The check quadrat had a complete cover of vegetation composed of 80 percent browse species, 2½ percent grasses and sedges, 3½ percent lichens, 5 percent mosses, and 9 percent weeds (*Petasites* and *Pedicularis*). During the 9-year period over which the observations were made several changes in the composition were noted, but the general ratios of the browse, weeds, grasses, and mosses remained nearly the same. Several new weed species appeared, among them *Arnica, Artemisia, Aconitum, Equisetum,* and *Polemonium,* and willows disappeared. The last charting showed a complete ground cover

5 percent grasses, 11 percent weeds, 80 percent browse species, nd 4 percent lichens and mosses.

Summary.—On completely denuded areas, as represented by he spaded quadrat, the initial invasion was by mosses and *quisetum.* Following these were the grasses and weeds, rep-
esented by such species as *Calamagrostis, Carex, Petasites, renaria, Polemonium,* and *Artemisia.* Browse species were the st to become reestablished.

When the vegetation was removed by cutting a more rapid re-
egetation occurred. This was likely due, at least in part, to the able roots left after cutting the aerial portions. Weed species, specially *Equisetum,* were aggressive in recovering the area nd browse plants also made rapid progress. Essentially the ame species were found in the new vegetative cover as were iginally present, but the disturbance caused considerable hanges in their specific abundances.

Changes in composition were noted also in the undisturbed heck quadrat. Although they were quantitatively of minor nportance, it is possible that these changes may reflect an un-
abilized condition of the type.

LICHEN-BROWSE TYPE

DEXTER CREEK

The lichen-browse type is typical of the lower hills back from he coast on Seward Peninsula. The soil is well drained, shallow, cky loam, with a thin humus layer on the surface. Soil mois-
ure is plentiful during the spring and fall, but scant in summer. he vegetation is made up largely of lichens with a small percent-
ge of browse, mosses, and sedges. This type is of major impor-
nce, as it furnishes a large part of the winter forage for the indeer in that section.

The site chosen for the study was about 7 miles north of Nome the Dexter Creek drainage. The plot, on a 20-percent north ope, was at an elevation of approximately 750 feet. A fenced closure containing four 1-meter-square quadrats was estab-
shed there in 1922 (fig. 14).

Half-cut quadrat.—The first of these quadrats when estab-
shed had a full cover of vegetation, composed of 92 percent lich-
s (*Cladonia alpestris, C. sylvatica, C. sylvatica sylvestris, C. ngiferina* and *C. uncialis,* 80 percent; and *Cetraria islandica,* 12 ercent); 5 percent browse (*Ledum*); and 3 percent sedges. The hens averaged 4 inches in height. The top half of the vegeta-
on was removed by cutting to simulate light grazing. Five ears after establishment of the quadrat the density of the veg-
ation was estimated to be 0.3, the plant cover being com-
osed of 38 percent browse (*Empetrum,* 15 percent; blueberry,) percent; ground birch, 5 percent; *Ledum,* 4 percent; and cran-
rry, 4 percent); 42 percent lichens, and 20 percent sedges. The oportion of browse species and sedges had increased markedly, t this was due largely to decrease in density rather than to any eat increase in the area covered by these species.

Nine years after establishment of the quadrat the vegetatio again had attained a complete cover of 1.0 density. This wa composed of 25 percent browse (*Empetrum, Ledum,* cranberr willow, and ground birch); 67 percent lichens; and 8 percen sedges. The last examination, made in 1932, disclosed littl change from the 1931 charting.

Light cropping, as typified by the one-half cutting, greatl reduced the stand of lichens and at the same time appeared t have stimulated the growth of browse and sedges. This stimula tion was likely due to the sudden release of these plants fro competition with the lichens. Several browse species invade among them *Empetrum,* cranberry, ground birch, willow, an blueberry. The sedges did not respond as readily as did th browse species and as the lichens returned were rapidly reduce

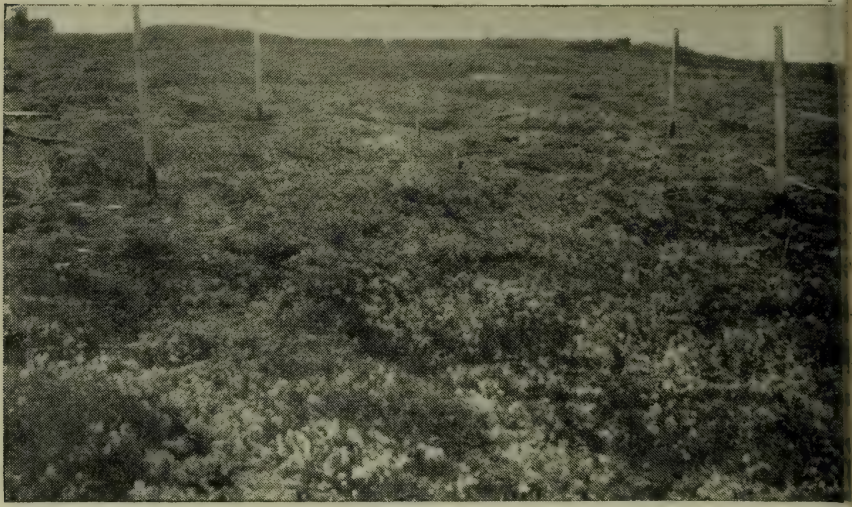

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Figure 14.—The exclosure in the lichen-browse type on Dexter Creek. October 2, 1928.

to their original status. The lichens made little recovery during the first 5 years after cutting, but during the second 5-yea period they spread over much of the quadrat and attained a height of about 2 inches.

Denuded and trampled quadrat.—This quadrat had a complet cover composed of 92 percent lichens, 5 percent browse, and 3 per- cent sedges. The lichens were 3 to 5 inches in height. The are was denuded of vegetation and trampled. Five years later, i 1927, the density of the plant cover was estimated to be 0.1. The vegetation was composed of 45 percent browse, 15 percent sedges, 30 percent lichens, and 10 percent weeds.

In 1932, ten years after denudation of the area, the vegetatio had an estimated density of 0.4 and was composed of 45 percent browse, 5 percent sedges, and 50 percent lichens. Most of the lichen growth was around the edges of the quadrat but some new growth was beginning in the center.

In this instance the denuded area was revegetated by the same species that were originally found on the area. The rate of revegetation was very slow, and indicated that it would probably require 25 years for the complete return to original condition of density, composition, and volume. Browse species and sedges recovered more rapidly than did the lichens.

Picked quadrat.—The vegetation on the third quadrat in this group was very similar to that of the others, namely, a complete cover composed of 92 percent lichens, 5 percent browse, and 3 percent sedges. The lichens were picked by hand and the browse and sedges left undisturbed. Five years later, in 1927, the vegetation was estimated to be of 0.25 density and was composed of 33 percent browse, 17 percent lichens, 45 percent sedges, and 5 percent weeds. Ten years after establishment of the quadrat, in 1932, the cover density was estimated to be 0.55, the vegetation consisting of 45 percent browse, 20 percent sedges, and 35 percent lichens. Most of the lichens were creeping in from the edges of the quadrat but a few groups of fair size were found within the interior of the plot. They averaged 2 inches in height.

The removal of the lichens was followed by an increase in browse and sedges. This no doubt resulted from removing competition by the lichens as well as from opening the stand and affording more suitable areas for the establishment of new individuals. The browse species thus established persist, but the sedges are crowded and killed out by the advancing lichens.

Check quadrat.—At the time of establishment of the check quadrat in 1922 it had a complete vegetative cover of approximately 90 percent lichens and 10 percent browse and sedges. The lichens averaged 4 inches in height. The last examination, made in 1932, disclosed complete cover density (1.0), the plant composition being 77 percent lichens, 20 percent browse, and 3 percent sedges. At first glance it would appear that the lichens had decreased and had been replaced by browse species, but this was not actually the case. In charting, the areas occupied by the browse species were outlined, and it is apparent that they have expanded, but lichens were found underneath and intermingled with the prostrate browse forms as abundantly as when the quadrat was established. It is merely a shortcoming of the system of charting that creates the illusion. Actually little change in the vegetation of this check quadrat took place during the 10 years of observation.

Summary.—Light cropping, as exemplified by the half-cut quadrat, was followed by the most rapid recovery that was made in any of the tests in this lichen-browse type. After heavy cropping, as on the picked and on the denuded and trampled quadrats, fully twice as much time was required for recovery, which in all cases was slow. Nine years were required for the half-cut quadrat to reestablish a full cover of vegetation, and the lichens did not occupy as large an area in it, nor were they as tall in growth, as originally.

Open herding, with possibly a 10-year rotation, would seem to be a practical system of utilizing this type. It would afford sufficient time for the lichens to recover and so maintain forage pr duction. Under no consideration should reindeer be allowed o the area during the summer and early fall when the lichens ar dry and brittle.

WOODLAND-MOSS TYPE

UNALAKLEET

The woodland-moss type occurs most frequently along th larger drainages in the Norton Sound region, but is found als farther back in the interior. The vegetation is characterized b birches and alders with an understory of lichens, mosses, grasse weeds, and small browse species. The soil is shallow and rock but frequent summer rains furnish sufficient moisture to suppor a vigorous stand of vegetation.

The site chosen for the study of this type was on the stee south slope of a bluff on the north side of the Unalakleet Rive about 7 miles from its mouth, at an elevation of approximatel 300 feet. Five open quadrats were established there near th top of the bluff.

Scraped and cut quadrat.—The first of these quadrats, whe established in April 1922, had a vegetative cover of 87 percen lichens, 10 percent mosses, and 3 percent grasses. The densit of the cover was 1.0. The vegetation was removed by firs scraping and then cutting to the frozen ground surface. Th purpose of establishing the quadrat was to observe the effect o close cropping of lichens and to determine the quantity of forag in the stand. Later, when the ground had thawed, there remaine on the ground a cover of moss (*Polytrichum*) 1½ inches deep The lichens had been entirely removed. The air-dry weight of th lichens taken from the quadrat was 3.46 pounds, which indicate a forage yield of 14,000 pounds to an acre.

Seven years after establishment of the quadrat the vegetatio had recovered to a 0.95 density. It was made up of 25 percen lichens, 65 percent mosses (*Polytrichum*), and 10 percent grasses The lichens averaged 1½ inches in height.

The quadrat recovered from a denuded condition to one o almost complete density in 7 years. *Polytrichum* was greatly stimulated by the removal of the lichens and was active in revegetating the area. Grasses responded only weakly to the reduction in cover. The reestablishment of lichens on this area was rapid.

Picked quadrat.—The second quadrat in this group had a complete cover of vegetation in 1922, composed of approximately 90 percent lichens, 7 percent mosses, and 3 percent grasses. *Stereocaulon* was the dominant lichen. The vegetation was removed from the quadrat by hand picking. By this method the lichens were readily removed to the frozen surface. The object was to observe the effect of moderately close cropping of lichens to determine the quantity of forage produced. The air-dry weight of the lichens removed from the 1-meter-square quadrat was 3.25 pounds, which indicated a forage production of 13,152 pounds to an acre. Later, when the ground had thawed, it was found that a cover of moss (*Polytrichum*) 1½ inches deep still remained on the area. The lichens had been entirely removed.

The last observation, made in 1932, disclosed a vegetative cover of 0.975 density composed of approximately 70 percent lichens, 28 percent mosses, and 2 percent grasses and weeds. The lichens were 60 percent *Stereocaulon* and 10 percent *Cladonia*. They averaged 3 inches in height. Many small, new lichens also were noted in the more open spaces.

The quadrat recovered from a nearly denuded condition to about the original density in 7 years. The lichens almost completely recovered their density and closely approached their original height in 10 years, much of this growth taking place during the last 3 years of the period. *Equisetum* came in rapidly following the denudation but was as promptly replaced by the spreading lichens and mosses. It is indicated that moderately close cropping, as typified by the picking treatment, is not so severe a treatment as scraping and cutting. The recovery of the vegetation, especially that of the lichens, was much more rapid than that following the scraping treatment. The grasses showed little response to the opening of the stand of vegetation. This quadrat again demonstrated that grazing such as would result under a system of open herding is the most advantageous method of utilizing lichens. It also emphasizes the necessity of employing a long rotation in order that the vegetation may recover after use.

Check quadrat No. 1.—The check quadrat in this group (fig. 15) had a vegetative cover of 90 percent lichens, 9 percent mosses, and 1 percent grasses. The lichens averaged 2½ inches in height. By 1929, seven years after establishment of the quadrat, the

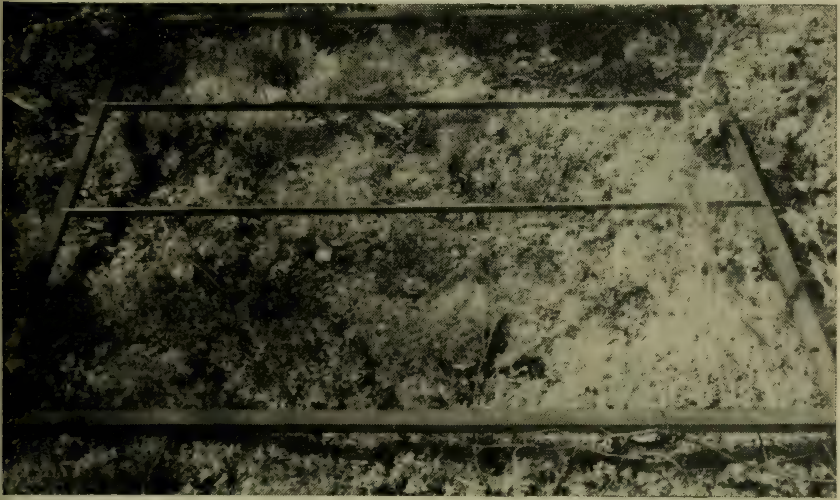
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Figure 15.—The check quadrat in the woodland-moss type near Unalakleet. August 24, 1929.

density of the vegetation had been reduced to 0.9. The compo tion was estimated to be 80 percent lichens, 15 percent mosse and 5 percent grasses. Bare areas had developed. When t area was last examined in 1932 the density of the vegetation w estimated to be 0.8. Lichens made up 80 percent of the cove with mosses the remaining 20 percent. The average height the lichens was 3½ inches. Some very small new lichen grow was noted in the previously bare areas.

The opening up of the lichen stand on this quadrat allowe the mosses to increase. The lichen growth appeared, but t increase in mosses and lichens was not rapid enough to mainta a complete vegetative cover. The cause of this reduction of t lichen stand is not known and further observations should made.

Check quadrat No. 2.—The fourth quadrat in this group wa established in 1929. The vegetative cover was complete and wa composed of 85 percent lichens, 10 percent mosses, and 5 perce weeds (*Epilobium* and *Equisetum*). When the area was las examined in 1932 the density of the vegetation was estimated t be 0.975. The cover was composed of 95 percent lichens, 4 pe cent mosses, and 1 percent weeds (*Equisetum*). The lichens ave aged 4 inches in height. It appears that lichens increased on thi quadrat, displacing the mosses and weeds. These observation however, are not complete enough as yet to warrant definite con clusions.

Quadrat No. 5.—The fifth quadrat in this group was als established in 1929. It appeared to have been badly trample and it is thought that the area may have been scraped in 1922 There was a scattering of dead lichens as though the area ha been grazed. The density of the vegetation was 0.6 and it wa estimated that half of it was dead. *Stereocaulon* made up 6 percent of the total cover. In 1932 the plant density was 0.8, an it was estimated that the vegetation was composed of 90 percen lichens, 6 percent mosses, and 4 percent birch, *Carex, Equisetum* and *Epilobium.* The vegetation on this area appeared to b changing rapidly, but these observations are, as yet, too meage to be conclusive.

ALPINE-DRYAS TYPE

EGAVIK

The alpine-dryas type occupies the summits of the higher ridges and hills back from the coast in the Norton Sound region. It is not of much economic importance as forage for reindeer because of its short growth. It is chiefly valuable for holding the soil against erosion, conserving moisture, and serving as forage for such rodents as parka squirrels and marmots. The vegetation is composed largely of low-growing mat forms, of which *Dryas octopetala* is the most important. *Antennaria* and *Phlox* also are found in this type, along with a few sedges and such fine grasses as *Poa* and *Festuca.* The soil is shallow and rocky, with a slight layer of humus. Soil moisture is plentiful during the spring and fall, owing to melting snow and seasonal rains, but during the summer it is scanty.

In order to study the trend of plant succession in this type, an exclosure (fig. 16) was erected around three quadrats, and two unprotected quadrats were established nearby. These quadrats were marked out in 1929 on top of a high ridge a mile or so north of Egavik, near latitude 64° N., longitude 161° W.

Spaded quadrat.—When established within the exclosure this quadrat had a cover of 0.5 density composed largely of *Dryas* and *Tofieldia.* The plants were completely removed from the quadrat by spading it. After 3 years the total growth on the area consisted of 6 *Carex* clumps, 1 of *Phlox,* 1 *Astragalus,* 1 *Aster*, 2 *Dryas,* 1 willow, and 6 of mosses.

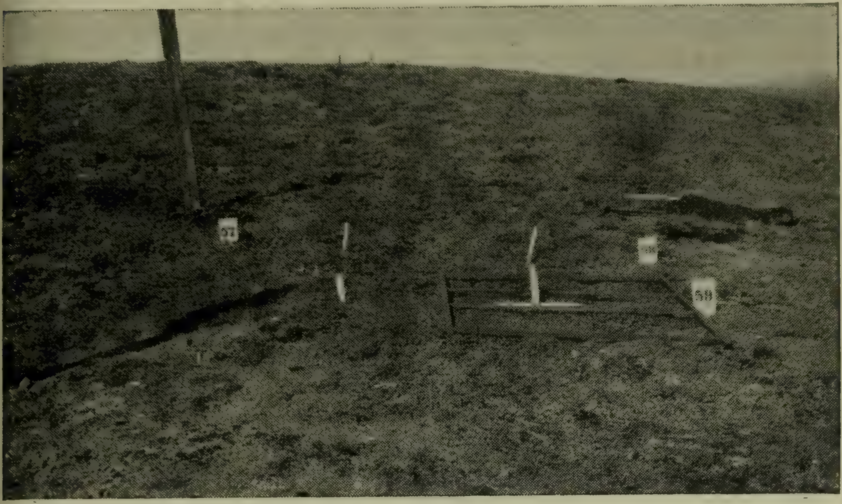

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Figure 16.—The exclosure in the alpine-dryas type near Egavik at the time of establishment. August 23, 1929.

The vegetation had been heavily frosted when the last examination was made, and it is possible that some seedlings of grasses and weeds were overlooked. The *Dryas* and willow appeared during the third year after denudation of the area. These data are far too meager and the study was of insufficient duration to show anything conclusively, but it appears that the same species return to an area following denudation. The recovery of the vegetation was slow.

Cut quadrat.—The vegetation on the second quadrat within the exclosure was removed by cutting it at the ground surface, leaving the roots and soil undisturbed. Before cutting, the vegetation had a density of 0.6 and was composed of *Dryas* and *Tofieldia.* Two years later the vegetation was of 0.3 density and had a high percentage of *Poa* and *Carex. Dryas* had made a strong recovery, undoubtedly by regrowth of viable roots left in the soil by the cutting. *Antennaria, Phlox,* and *Astragalus* also were present and making good growth. The third year after cutting, further expansion of the mat forms *Dryas, Phlox,* and *Antennaria* was noted. Fewer grasses and sedges were found, but this may have been due to these plants having been frosted and withered, and for that reason overlooked. The same species that made up the original plant cover were active in revegetating the denuded area. Further study is necessary before definite conclusions can be drawn.

Check quadrat.—The third quadrat in this exclosure was left undisturbed. The cover at the time of establishment of the area was of 0.7 density and was composed largely of *Dryas* with a few scattering plants of *Astragalus, Tofieldia,* and *Festuca.* In 1932, three years after establishment of the quadrat, the density of the vegetation was estimated to be 0.85, an increase due to the spread of the *Dryas* mats. Lichens appeared in 6 small areas. It is indicated that this vegetative type is unstable and that it is still in active adjustment to its habitat. Further observations should be made.

Denuded open quadrat.—This quadrat, located outside the exclosure, was denuded of vegetation by grubbing and pulling the plants. Before the area was denuded, the vegetation had a density of 0.7 and was composed of 85 percent *Dryas,* 10 percent *Tofieldia,* and 5 percent *Antennaria, Astragalus,* and *Draba.* Two years later the cover was estimated to have a density of 0.15. *Dryas* was invading from the edges and a few plants had become established within the area. *Phlox, Antennaria,* and *Astragalus* also had reestablished themselves. *Carex* and *Poa* were well represented and a few small patches of lichens were noted. Three years after establishment of the quadrat the mats of *Dryas, Phlox, Antennaria,* and *Astragalus* were found to be much the same as they were the previous year. Sedges and grasses were not seen. They may have been frosted down and thus escaped notice or they may have been grazed by reindeer. Further study should be made of this area.

Check open quadrat.—When the check open quadrat was established, the vegetative cover had a density of 0.7 and was composed of 85 percent *Dryas,* 10 percent *Tofieldia,* and 5 percent *Draba, Astragalus,* and *Antennaria.* During the 3 years the quadrat was observed little change occurred. The area occupied by *Dryas* increased slightly.

OVERGRAZED-TUNDRA BROWSE-LICHEN TYPE

STUART ISLAND

The overgrazed-tundra browse-lichen type is characteristic of the drier tundra in the Norton Sound region. The soil is loam, with heavy humus, and is of unknown depth. It is of volcanic origin. Because of frequent fogs and rains, soil moisture is plentiful throughout the growing season. Reindeer were grazed on Stuart Island during the winter prior to and during 1918, but not after that time. In that comparatively brief period, however, the island was overgrazed.

In 1920 a fenced enclosure (fig. 17), containing one 1-meteruare quadrat, was established to determine the length of time quired for this type of range to recover from overgrazing. At at time young lichens of $\frac{1}{8}$ to $\frac{1}{4}$ inch in height were beginning appear. Sedges, *Polytrichum, Empetrum, Arctous* and *Ledum* so were found. From examination of the chart it is assumed that is vegetation had a density of approximately 0.3. Subsequent exninations revealed steady progress up until 1931, when the last amination was made. The vegetation then had an estimated nsity of 0.95 and was composed of 15 percent lichens (*Cladonia,* *Cetraria,* 3; and others, 8); 50 percent browse (*Empetrum,* 15; *rctous,* 16; cranberry, 7; and *Ledum,* 12); 8 percent sedges, nd 27 percent mosses (*Polytrichum,* 12; and common moss, 15).

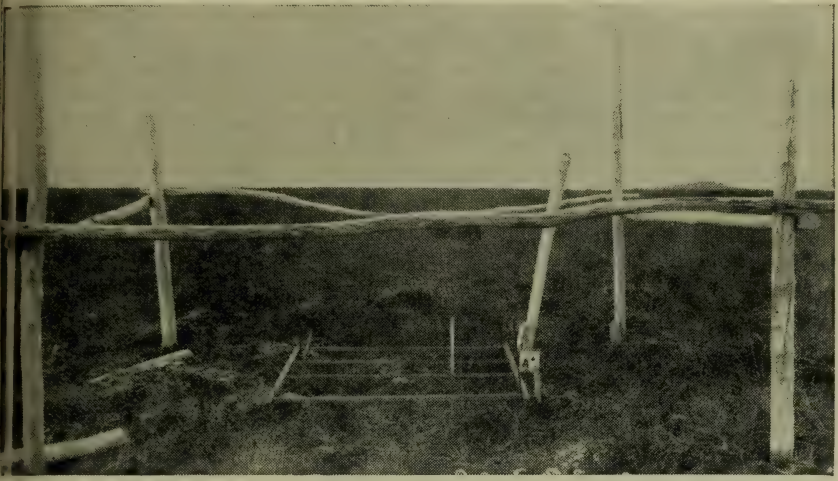

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Figure 17.—The study area on overgrazed browse-lichen tundra on Stuart Island. August 31, 1929.

Lichens increased rapidly at the start but during the later years ade slower progress. Browse species, especially *Empetrum* nd *Arctous,* were most aggressive in revegetating this overrazed type. Sedges made little progress and were rapidly relaced by the lichen and browse species. Judging from the bserved rate of recovery, it will require 25 or more years for this vergrazed type to be completely restored. It appears that the pecies originally found on the area are those which revegetate it, nd that in time the proportions of the species will become about he same as before.

OVERGRAZED-TUNDRA SEDGE-WEED TYPE

PASTOLIK

The overgrazed-tundra sedge-weed type is common near the oast of lower Norton Sound. The vegetation is characteristically mixture of sedges, weeds, and small *Eriophorum* clumps or niggerheads.” The soil is rather shallow and rocky, but has a fair supply of humus. Although the area is well drained, mo ture is plentiful owing to frequent local rains.

The type was heavily overgrazed by reindeer when an exclosu containing one 1-meter-square quadrat was erected on it in 19 The vegetation was made up of sedges and weeds and had estimated density of 0.1. The plants were in a noticeably weaken condition. The first year of protection brought a noticeak increase in the sedges, *Equisetum* and *Dicranum*. Two invadi species of the genera *Saxifraga* and *Thalictrum* also were foun The next year the cover density had increased to 0.35, a *Gentiana* was added to the plant population. Four years aft establishment of the quadrat the density appeared to be 0.6, a among the invading species were found *Juncus, Poa, Arctagrost* primrose, vetch, clover, *Empetrum,* and *Saussurea.* The quadr was then abandoned as the site was included within a newly co structed reindeer corral.

During the 4 years that the quadrat was studied the vegetati made substantial recovery. The original sedge-weed cover, whi was nearly destroyed by overgrazing, seemed to be returni under protection.

OVERGRAZED BROWSE-GRASS TYPE

CHORIS PENINSULA

The overgrazed browse-grass type occurs on top of the ma ridge of Choris Peninsula which partly separates Kotzebue Sour from Eschscholtz Bay, at latitude 66° 15′ N., longitude 162° V

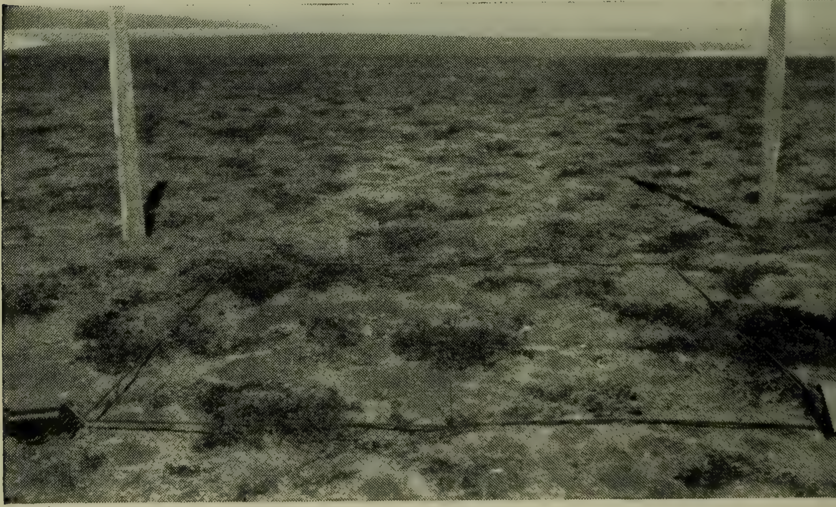

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Figure 18.—The exclosure site in the overgrazed browse-grass type on Choris Peninsu August 7, 1928.

The vegetation consists mainly of browse, ground birch, willo *Ledum,* and *Empetrum,* with a small proportion of sedges a rasses. Weeds are few and lichens are scarce. The soil is hallow and rocky, with scant humus. Soil moisture is plentiful uring spring and fall, but because of the sparse vegetation and he lack of humus, the moisture-holding capacity is low, and uring the summer the soil becomes dry.

Choris Peninsula in years past was used as a holding pasture or reindeer and as a result it became overgrazed. The vegetative over was greatly depleted and in places almost completely re-ioved. In 1928 an exclosure containing four 1-meter-square uadrats was located on top of the main ridge of the peninsula o study the effect of overgrazing, denudation, and partial denuda-ion on this vegetative type (fig. 18).

Cut quadrat.—The first quadrat in this group had a vegetative ensity of 0.4. The cover was made up of 90 percent browse *Empetrum*, 35; *Ledum*, 35; ground birch, 10; and willow, 10), percent grasses, and 5 percent weeds (*Tofieldia*, 2; *Oxycoccos*, ; and *Phlox*, 1). The vegetation was removed from the area by utting it at the ground surface. In 1932, four years after stablishment of the quadrat, the total plant population consisted f 6 willows, 3 plants of *Ledum*, 1 of *Phlox*, 1 clump of grass, nd 2 small patches of lichens. The lichens were first noted in 931.

The recovery of the vegetation in this type is very slow, al-hough observations were too few to serve for further conclusions.

Spaded quadrat.—The second quadrat in this group had in 1928 cover density of 0.25. The vegetation was composed of approxi-iately 90 percent browse (*Empetrum*, 42; *Ledum*, 42; and willow,), 5 percent grasses, and 5 percent weeds (*Tofieldia*). The plot as denuded by spading. In 1931 plant growth consisted of 5 mall clumps of grass, 3 of *Carex*, 2 willows, 1 plant of *Ledum*, 1 f *Phlox*, and 2 small patches of lichens. In 1932 the vegetation ad increased to 5 small grass clumps, 12 of *Carex*, 1 *Eriophorum* eedling, 2 willows, 1 plant of *Ledum*, 1 of *Phlox*, and 12 small chen patches. The largest *Carex* clump found in 1931 appeared o be dead in 1932. The willows were sprouts from roots left fter spading. Lichens, largely *Alectoria*, were increasing rapid-y. Mosses were thinly scattered over the area.

The recovery of the vegetation on this spaded quadrat was very low, although it was more rapid than that on the cut quadrat.

Check quadrats.—The third quadrat in this group was left un-isturbed to serve as a check for comparison with the treated uadrats. When established in 1928 the plot had a vegetative over of 0.3 density, and was composed of 98 percent browse ground birch, 45; *Ledum*, 45; ground willow, 5; and *Empetrum*,) and 2 percent weeds (*Phlox*). By 1932 little change had oc-urred. The browse species exhibited some growth, and a few ichens and sedges had appeared. Vegetative changes appear to ake place slowly in this type.

The fourth quadrat in the group was also left undisturbed, ut little change was noted in its vegetation during the 4 years t was under observation.

Open quadrat.—A quadrat was established in the open, not far from the exclosure, in order to make comparison between th vegetation inside and that outside the exclosure and to determin the effect of summer grazing on this type. When this plot wa established in 1928 the vegetation had a density of 0.3 and wa composed of 88 percent browse (ground birch, 45; *Empetrum* 20; *Ledum,* 20; and willow, 3), 6 percent grasses, and 6 percen weeds (*Phlox* and *Tofieldia*). In 1932 it was noted that 3 smal patches of lichens (*Alectoria*) had appeared. This was the onl significant change. The rest of the vegetation appeared thrifty There was no grazing on the Choris Peninsula during the perio of these investigations.

DENUDED CORRAL SITES

PASTOLIK

The corral site at Pastolik was originally in the browse-gras tundra type. The corral was used from 1922 until 1925, an during that time the area studied was completely denuded o vegetation. In 1927 four 1-meter-square quadrats were established within a fenced exclosure to determine the time required t reestablish a vegetative cover and the plant species composing it. The soil is deep, with a top layer of humus that is peatlik in appearance; moisture is abundant. It is probable that th area is underlaid with ice, as considerable heaving and settling of the ground has occurred since the quadrats were established

When the first plot in this group was established in 1927 ther were 6 grass plants growing on it. These plants were too small for accurate identification but were thought to be *Arctagrostis.* The vegetation recovered steadily, and in 1931 a cover of 0.5 density was attained. It was composed of approximately 75 percent *Arctagrostis,* 13 percent *Carex,* and 12 percent *Eriophorum.* One weed seedling, too small for identification, was observed.

The second quadrat in this group was completely barren in 1927. No plants were observed on the area in 1928, but in 1931 six plants of *Arctagrostis* were found.

The third quadrat in the group contained 1 plant of *Arctagrostis* when it was established in 1927, and by 1931 there was merely a small clump of this grass formed by stooling of the original plant.

The fourth quadrat contained 11 grasses and 1 weed in 1927. In 1928 there were 12 individual grasses. By 1931 the vegetation had increased until its density was approximately 0.35, and was composed of 65 percent *Arctagrostis,* 25 percent *Carex,* and 10 percent *Eriophorum.*

The revegetation of this denuded corral site took place very slowly. Grasses (largely *Arctagrostis*) and sedges (both *Carex* and *Eriophorum*) were the most active invaders.

CHORIS PENINSULA

The corral site on the Choris Peninsula is on the low, narrow neck at the north end. In 1927 the reindeer corrals were moved

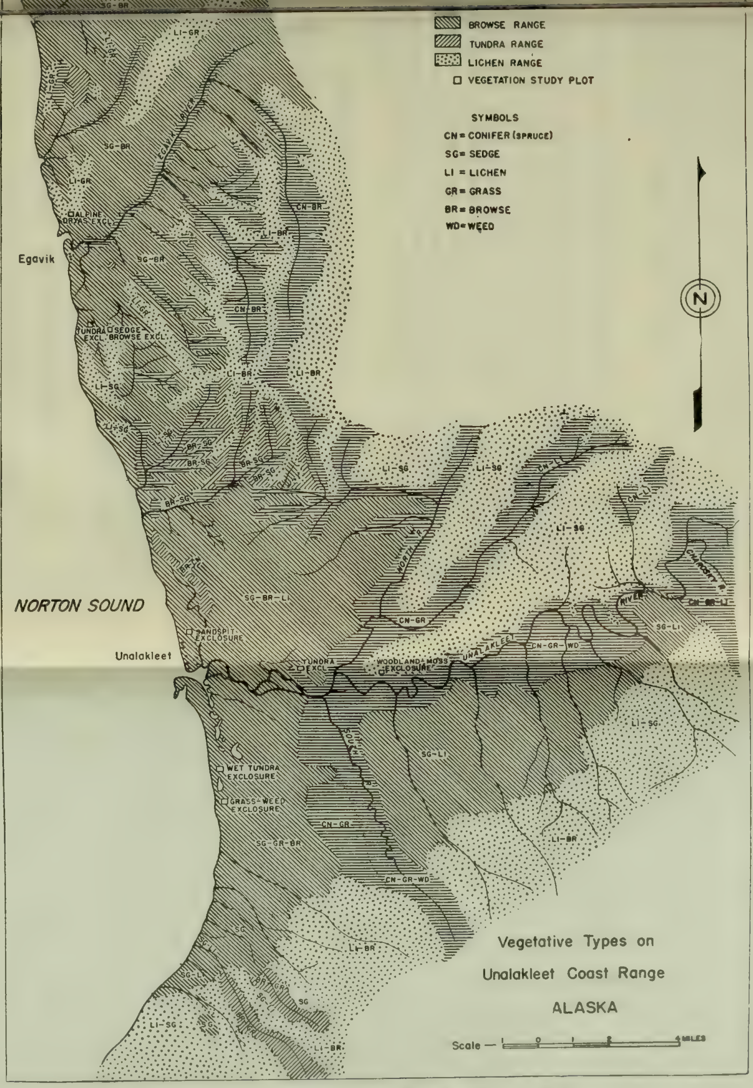

Figure 19.—Vegetative types on the Unalakleet-Egavik Reindeer Allotment on the Bering Sea coast, Alaska.

and this quadrat location was excluded. The plot was not further disturbed during the period of these investigations. In 1928 the vegetation was of 0.2 density and was composed of 90 percent yellow mustard and 10 percent *Polygonum* and an unidentified grass. By 1932 the density of the growth had increased to 0.8, the vegetation consisting of 70 percent *Ranunculus* and 30 percent musard. Several clumps of *Poa* and *Carex* were also present and ppeared to be increasing in size.

The vegetation on the plot increased greatly in density and howed a marked change in composition in the 5 years following ts establishment.

UNALAKLEET-EGAVIK REINDEER ALLOTMENT, BERING SEA COAST

The vegetation type map of the Unalakleet-Egavik Reindeer Allotment on the Bering Sea Coast (fig. 19) shows the distribution of the vegetative types over a representative part of the Bering Sea coast of Alaska. It will be noted that the spruce-browse and spruce-grass types are confined to the borders of the larger streams and are, therefore, narrow in outline. The sedge, or "niggerhead," tundra occupies the low benches and flats back from the streams and occurs on the first low hills. Farther back, on the higher hills, on better drained and drier sites, the lichen-browse, lichen-grass, and browse-grass types are found.

KOKRINES REINDEER ALLOTMENT, LOWER YUKON RIVER

The vegetation type map of the Kokrines Reindeer Allotment on the lower Yukon River (fig. 20) shows the distribution and abundance of the vegetative types on an area typical of the interior of Alaska. The Kokrines area lies in the drainage of the Melozitna River, a tributary of the Yukon, at latitude 65° N., longitude 155° W., north of the village of Kokrines on the Yukon. The lay of the land does not differ greatly from that of the Bering Sea coast although generally the mountains in the interior reach greater elevations. A striking difference in the plant cover is seen in the greater proportion of spruce and woodland types. The tundra types are found at lower elevations and on the flats near the larger streams and there is a greater proportion of browse tundra.

SUMMARY AND CONCLUSIONS

The northern and western parts of Alaska support a varied and abundant vegetative cover that serves as forage for numerous native animals as well as for the introduced reindeer. The interior of this region is occupied principally by the boreal forest, although extensive areas of tundra prevail in the valleys and on upland slopes. The tundra, a treeless, prairielike plain along the coast, varies in width from a few miles to approximately 200 miles and extends from the Aleutian Islands northward to Point Barrow and eastward along the Arctic coast into Canada.

In study of reindeer management, particular attention was given to the tundra and to the lichen vegetation that is so important as winter forage. This report presents the data obtained from 77 test quadrats, some of which were observed over a period of 14 years. These plots were distributed within the tundra belt bordering the Bering Sea and Arctic Ocean from Nunivak Island on the south to Choris Peninsula on the north.

The vegetative types considered are beach-transition, sand-dune and sandspit, grass-browse, wet and dry tundra (including sedge), lichen, heath, woodland, and alpine. The tundra is a patchwork of plant societies representing varying degrees of composition and stages in succession. Where the tundra immediately along the coast formerly supported an abundance of lichens, now as a result of summer grazing the lichen cover has largely been replaced by cotton-sedge, mainly *Eriophorum callithrix,* and by shrubs. The average plant composition of the tundra as a whole is about as follows: Lichens 30 percent, shrubs 25 percent, sedges 25 percent, and grasses, weeds, and mosses 20 percent.

Of the lichens, chiefly the forms of taller growth are herein treated. Species of *Cladonia* predominate, followed in order by those of *Cetraria, Alectoria,* and *Stereocaulon.* The lichen stand is often considerable and forms the principal winter food of the reindeer. Sampling of numerous areas indicated a forage production of 5 to 7 tons, air-dry weight, to an acre. Areas sampled were those in which the lichens comprised from 50 to 90 percent of the vegetation. *Cladonia,* because it was most abundant and of taller growth, generally gave the largest yields.

Shrubs form an important part of the tundra plant composition. On the wet sites, prostrate willows are abundant. In drier places, ground birch is a prominent shrub, being of taller growth in the interior. In addition, crowberry (*Empetrum nigrum*), Alaska tea (*Ledum*), blueberry and cranberry (*Vaccinium*), cloudberry (*Rubus chamaemorus*), and bearberry (*Arctous alpina*) occur frequently throughout.

Moderate utilization of the beach-transition, sand-dune, and coast-sandspit types tend to stabilize the cover to a composition of grasses and weeds. Such cover produces more palatable spring and summer forage than do the browse-lichen and browse-moss associations of the adjoining tundra. Overgrazing opens the stand to invasion of mosses, reduces the quantity of forage, and exposes the soil to erosion by wind and rain.

In the tundra-lichen types, the range is quick to react to any disturbance. The length of time required for its recovery is directly proportional to the degree of disturbance. Trampling has a greater damaging effect upon lichens than has grazing or even removal of the plant cover. Disturbance of the lichen cover on a moist site is followed by an almost immediate invasion of vascular plants, chief of which is cotton-sedge (*Eriophorum*). The rate of invasion is in direct proportion to the amount of disturbance. On dry sites, the reduction of lichens through grazing is followed by an accelerated growth of shrubs. The recovery of lichens is more rapid on dry, than on moist, sites.

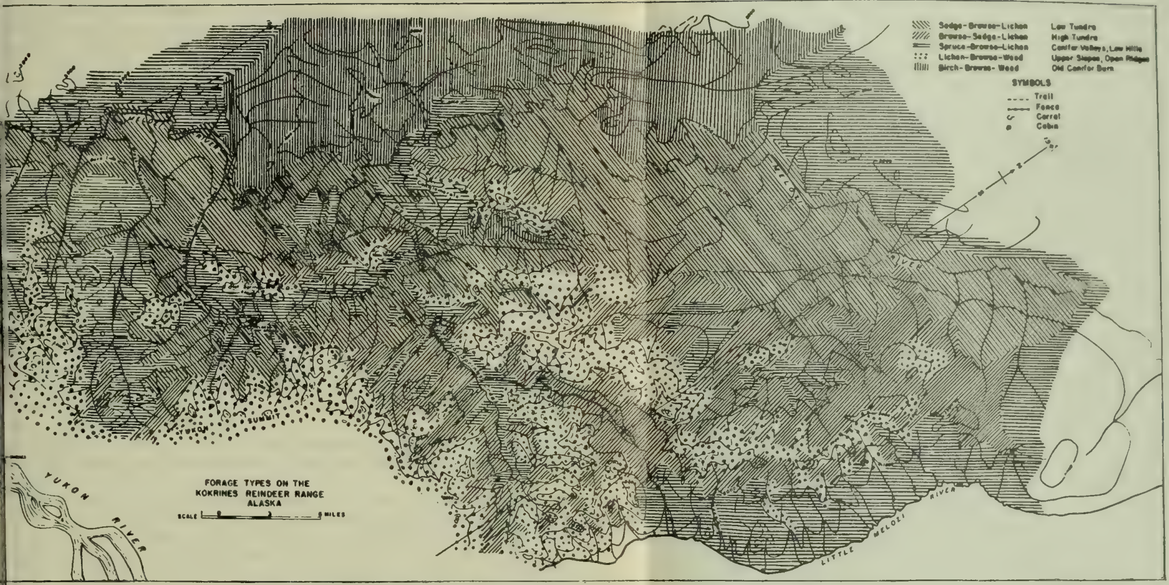

Figure 20.—Vegetative types on the Kokrines Reindeer Allotment on the lower Yukon River, Alaska.

In the tundra-sedge type, even moderate grazing tends to retard the vegetation of denuded or badly depleted areas on the drier sites. Summer grazing reduces the quantity of sedges and permits increased growth of browse species. On moist sites, however, the vegetation readily recovers after denudation of an area, an almost pure stand of *Carex* coming in first. Under protection, the density of cover increases and an invasion of grasses seems to follow. One season without protection was sufficient to undo the progress of 4 years and render the area substantially as it was when the studies were started.

The grass-browse type will bear heavy grazing. Following denudation of a plot the recovery to grass is rapid.

The heath type is unstable. After denudation of an area the initial invaders were mosses and *Equisetum*. Opening of the stand allows an increase in weeds. The shrubs recover slowly.

In the lichen browse type, recovery is rapid under light cropping but slow under heavy grazing. On this type open herding should be practiced and the range should not be used during the summer and early fall when the lichens are dry and brittle and thus easily destroyed by trampling.

Opening of the woodland moss stand allows competition of the mosses with the lichens. In this type recovery after overgrazing is slow, but a recovered stand contains a large proportion of lichens.

In the alpine-dryas type recovery after denudation of an area is slow. Invasion is by *Dryas*, weeds, *Carex,* bluegrass, and lichens.

On overgrazed browse-lichen tundra the browse species are the most aggressive in recovery, followed by lichens. It is indicated that complete recovery would require probably 25 years or more.

Substantial recovery was noted on overgrazed sedge-weed tundra (moist site) in 4 years.

Very slow recovery occurred on denuded browse-grass tundra (dry site) during a 4-year period. Invasion by grasses and sedges was most active.

Further study of the complex nature of the Alaska tundra is needed. The climax association of the Arctic tundra, ordinarily given as *Cladonia-Carex,*[7] is not readily verifiable, the present cover being unstable, although this may be due, in part, to grazing. Disturbance by grazing and fire, accompanied perhaps by climatic changes, has resulted in a general confusion in the plant mixture and occupation. The removal or depletion of the insulating plant cover allows the subsoil to thaw to greater depths and opens the surface to drainage. This, no doubt, contributes largely to alteration of site conditions and causes further vegetative changes. The advance of tree growth on the tundra indicates that the formation is as yet unstabilized.

The wet tundra seems less stable than the dry tundra. On both the recovery of lichens from grazing or fire injury is slow, whereas the invasion and reestablishment of vascular plants are rapid. A depleted lichen range under complete protection requires from 20 to 40 years for restoration to the original densit and height growth. Moderate grazing by open herding and rotational use, however, will permit sustained utilization of undamaged tundra range.

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[7] Plant Succession and Indicators, by Frederic E. Clements, 1928.

MANAGEMENT OF REINDEER ON NUNIVAK ISLAND

In 1938, the reindeer on Nunivak Island were estimated t number 12,000. During the next 6 years they increased in numbers until, in 1944, the Office of Indian Affairs estimated tha there were 30,000 reindeer on the island. Overuse of the winte lichen range has caused about a 15-percent depletion beyon normal carrying capacity.

Musk oxen, numbering 115 in 1943, are confined principally t the sand-dune type and the dry tundra range at the western en of the island. It is estimated that the suitable range total approximately 300 square miles.

On the basis of forage acres, the range capacity on Nuniva Island should carry 2,100 musk oxen and 8,000 reindeer. O the basis of this study and subsequent observations, it is recommended that reindeer be removed from the island until a population of 8,000 has been established. This is sufficient for native population of 195, and would permit an annual export o 1,300 carcasses.

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Albert M. Day, Director

Research Report 11

REACTION OF OYSTERS TO CHLORINATION

BY

PAUL S. GALTSOFF

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ABSTRACT

REACTION of oysters to free chlorine was studied by recording shell movement, measuring the rate of flow of water through the gills, and determining the beat frequency of the lateral cilia of the gills. Live oysters are sensitive to initial treatment with chlorine concentration of 0.01–0.2 parts per million, which causes the cessation of cloacal current and closure of shells. As repeated treatments develop tolerance, shell movement and pumping of water may continue at concentrations much stronger than those which produced the initial effect. Chlorine concentrations of about 0.2 p. p. m. reduce the beat frequencies of the lateral cilia from about 18 per second at 21°–22° C. to about 10 beats per second. Thus, the tolerance of the excised lateral cilia is far greater than the tolerance of an intact organism. Great variation in tolerance, observed in the experiments, is associated with the stimulation by chlorine of mucus secretion which acts as a protective coating of tissues. Experiments indicate that effective self-purification of oysters can be attained if their normal shell movements and pumping are not inhibited by free chlorine and the latter is used only for disenfecting the shells and sea water.

REACTION OF OYSTERS TO CHLORINATION[1]

By PAUL S. GALTSOFF, *PhD., Biologist, Division of Fishery Biology*

CONTENTS

Page
Introduction 1
Reaction of oysters to stimulation 3
  Method 4
  Effect of free chlorine on shell movement 9
  Effect of chlorine on the pumping mechanism of the gill 14
    Drop-counting method 16
  Effect of free chlorine on the rate of pumping 18
    The apron method 18
  Variations in stimulus threshold 21
Reaction of oysters to stimulation—Continued
  Protection against irritating substances 22
  Effect of uninterrupted chlorination on muscular activity and ciliary motion of the gills 23
Conclusions 26
Bibliography 27

INTRODUCTION

The use of free chlorine for the purification of shellfish was first applied in 1914 by James Johnstone and A. Scott in England in experiments conducted on mussels at the Piel Laboratory of the Lancashire and Western Sea Fisheries Committee. Johnstone's final conclusions (1914) were that "mussels may be cleansed from ingested sewage bacteria by keeping them in water sterilized by the addition of chlorine. A concentration of chlorine in sea-water of 5 parts per million is sufficient, practically, to sterilize the water, while it does not interfere with the ordinary functioning of the shellfish." The latter conclusion was not in agreement with the subsequent findings of R. W. Dodgson (1928, 1930) who carried out a comprehensive research on the problem of shellfish purification and found that free chlorine in the concentrations approximating those used by Johnstone greatly interferes with the functioning of the mussels.

In this country, experiments on purification of oysters with chlorine were conducted in 1914–15 by William F. Wells (1916) at the Fisherman's Island (Va.) laboratory of the United States Public Health Service. Noticing that under favorable conditions a continuous stream of food material flows through the intestinal tract of the oyster and that within 5 hours particles strained by the gills were being ejected with the feces, Wells arrived at the conclusion that the time required for purification would not be a prohibitive factor for commercial use of the process. Further studies of the application of chlorination of oysters on a commercial scale were made by F. A. Carmelia (1921) who concluded that "the process should be handled in much the

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[1] Approved for publication December 29, 1945. Research Report 11.

same manner that pasteurization of milk is controlled." He noticed that water containing hypochlorite of calcium, for a brief period following the addition of the chemical, is more or less irritating to the oyster, which "repeatedly and forcibly rejects it." With the disappearance of the "excess" of chemical from the water, the oyster resumes pumping. Following Dr. Well's work several plants for purification of oysters were established by the oyster companies at Inwood, Long Island, West Sayville, Long Island, and by the State Departments of Health in Massachusetts, New Jersey, and Virginia.

The problem of shellfish purification received particular attention in England where a plant for cleansing mussels has been in operation since 1916 at the Government Research Station, Conway, Wales. The report on this work, summarized by Dodgson (1928), contains detailed information regarding the behavior of edible mussels under different conditions of storage in tanks and their reaction to the presence of free chlorine in water. After more than 14 years of continuous research on mussels and oysters, the work of the British investigators established that the purification of shellfish is effected "solely by the physiological functioning of the shellfish themselves in sterilized water" (Dodgson, 1930). During the treatment used in Great Britain, the shellfish were not exposed to any chemical disinfectant until purification was completed, when they were treated with water containing 3 p. p. m. of free chlorine. Dodgson called attention to the formation of pseudo-feces, or accumulation of mucus discharged directly from the gills by sharp, shell movements and to the importance of fixing the sewage bacteria in the mucoid discharges. To obtain the desired degree of purification it was found necessary to place the shellfish on grids from which the feces and mucoid discharges could be washed away by hosing. Oyster purification, as advocated by Dodgson, consists in the following steps: (1) Placing the shellfish in the tank; (2) washing away adherent mud or other material; (3) keeping for 24 hours in sterilized water in which the free chlorine was neutralized by sodium thiosulphate; (4) draining and washing; (5) overnight treatment with second bath of sterile dechlorinated water; (6) draining and hosing, and (7) final bath for one hour with chlorinated water having a concentration of 3 p. p. m. of free chlorine. The purpose of the last bath is to sterilize the outside of the shells. The temperature of the water during purification should be not less than 13° C.

In 1936–37, experiments on cleansing and conditioning of oysters taken from the Lower Chesapeake Bay were made by the State of Virginia at the demonstration plant at Norfolk (R. Messer and G. M. Reece, 1937). The process, however, was limited to a relatively mall number of shellfish. During the 5 months of operation of the Norfolk plant only 165 bushels of oysters were conditioned.

The regulations of the United States Public Health Service permit he use of chlorinated water for the conditioning of oysters in water-ight tanks. The Manual of Recommended Practice (U. S. Public Health Service, first issue, 1943–44) specifies that water used for he conditioning of shellfish should carry "chlorine in solution of not less than 0.5 p. p. m. when determined by the ortho-tolidine test 5 minutes after the chlorine application" and that "applied water is maintained in such condition by the continuous or intermittent pplication of chlorine to it that the chlorine residual does not fall below 0.05 p. p. m."

Purification by chlorination is now being practiced in several coastal regions in preparing oysters for market. The process depends primarily on self purification for it is accomplished by the activity of the oyster in cleansing itself from excessive numbers of bacteria. Chlorine is used for disinfecting the outside of the shells and for sterilizing the water in which the oysters are placed. Purification cannot be accomplished if the oysters fail to open their valves or are unable to maintain a steady flow of water through their bodies. This experimental study was undertaken with the view of obtaining data which may be useful to the oyster industry and to Public Health officers in charge of shellfish sanitation. The work was carried on at the Marine Biological Laboratory, Woods Hole, Mass., using -year-old oysters from Narragansett Bay, R. I.; additional observations were made at the College Park Laboratory of the United States Fish and Wildlife Service with oysters from the Maryland part of Chesapeake Bay.

REACTION OF OYSTERS TO STIMULATION

Reaction of an oyster to outside stimulation can be studied by observing the shell movements, caused by the contractions of the adductor muscle, and by measuring the rate of pumping of water by the gills. The production and control of water current in the oyster is accomplished by several anatomically independent organs. The details of this rather complex process will be discussed by the author in a separate paper; for the purpose of the present study, it suffices to state that the pumping mechanism of an oyster consists of a large number of ciliated cells, so-called lateral cilia, arranged in long rows along the filaments of the gill, and that access of water to the gills is controlled by the adductor muscle and the mantle (pallium), a membrane-like organ underlying the shell. By beating inward, the lateral cilia force the water into the inner passages of the gill lamellae where an increased head pressure causes an efferent current of water. The water sucked in by the surface of the gills i forced through the water tubes, inner passages, and supra-branchia chambers, into a cloaca or into a promyal chamber and finally i discharged to the outside. The access of water to the gills is controlled by the opening or closing of the shells and by the positions o the two opposing borders of the mantle. Under certain conditions the shell may be wide open but the entrance to the branchial cavit may be completely obstructed by the pallium (Hopkins, 1933; Galts off, 1938, p. 467; Nelson, 1938). Thus, the fact that the shell of th oyster is open is not an indication that the animal is pumping wate and feeding.

Small openings on the surface of the gill, so-called ostia, are capabl of expanding or contracting (Elsey, 1935; Nelson and Allison, 1940 and therefore provide an additional mechanism which regulates th movement of water through the gill. Thus, the pumping of wate by the oyster is regulated by (1) the beat frequency of the later cilia; (2) muscular activity of the adductor; (3) position of the pa lium; and (4) degree of expansion of the ostia.

METHOD

Reaction of oysters to free chlorine was studied by recording th shell movements, by measuring, on the excised pieces of gill tissue, th beat frequencies of the lateral cilia, by recording the pumping eff ciency of the gill in the oysters which were prevented from closin their shells, and by recording the rate of water discharge by an inta oyster.

Shell movements were recorded by obtaining tracings on a kym graph drum rotating at a speed of about 1 inch per hour. Lever made of plastic, were attached to the flat (right) side of an immoblize oyster, the uppermost position of the writing points always correspon ing to the closed position of the valves.

The rate of beating of the lateral cells was measured by means of a electric stroboscope. Excised gill filaments, separated by fine needle were placed in sea water in a Syracuse glass or in a covered micr aquarium. A group of at least 10 readings was made at 1 minu intervals and temperature was recorded by means of a small the mometer immersed in the water. Control observations showed th the beat frequency varies in the different loci of the same filamen It was therefore necessary to confine observations to one locus of filament, a condition which presented considerable difficulty because the mobility of the excised pieces of gills and their tendency to rotat By anchoring the tissues with small pieces of glass, shells, or oth suitable material, the difficulty was to a certain extent avoided, b many observations could not be completed because of the change the position of the specimen and the impossibility of observing the same locus throughout the test.

The relative efficiency of the pumping mechanism of the gill was measured by means of an electric drop-counting method (Galtsoff and R. O. Smith, p. 172, 1935). In this method the valves of the oyster are kept open by placing a small wedge between them and inserting a rubber tube in the cloaca to intercept the water coming from the left demibranch. The oyster is placed in a constant-level tank of about 1-liter capacity and the free end of the rubber tubing is attached to a glass tube leading to a small vessel with an overflow. Prior to placing the oyster, the tank is filled with water and levels in the tank and in a small vessel are carefully adjusted. Each drop of water discharged by the oyster through an overflow from the small vessel falls between the two platinum electrodes and completes a circuit which activates the kymograph lever. Details of the set-up have been fully described in the papers of Galtsoff (1928) and Galtsoff and Smith (1935) and need not to be repeated here. The drop-counting arrangement used in the present experiments is shown in figure 1.

The drop-counting method permits studying the behavior of the pumping mechanism of the oyster without interference of the regulatory action of the adductor muscle and mantle. The method is, however, inadequate as was shown by Nelson (1938) for measuring the total amount of water pumped by the oyster. The latter value can be obtained by combining the constant-level tanks (Galtsoff, 1926) and the "apron" technique suggested by Nelson (1936). The oyster is wrapped in a rubber dam fashioned in the shape of a cone and sealed to the shells[2] in such a way that the entire dorsal half of the oyster is inside the cone, while its ventral half is free. The tip of the cone is cut off to make an aperture about 1 inch in diameter. The free end of the cone is slipped over a glass tube in the wall separating the small vessel from the larger tank. To insure free movements of valves and at the same time to prevent leakage of water between the shells and the rubber dam, small cotton pads are inserted at the hinge and at the edges of the valves. Before placing the oyster in the tank, a check is made of possible leakage of water through the seams of the cone. The oyster is immobilized by pressing it into a lump of plastocoele placed on a suitable platform. Connection between the shell and the writing lever is made with a small wire loop mounted with colophonium cement near the edge of the shell attached to the lever with a paraffined silk thread. The latter precaution is necessary to avoid shrinking and stretching of the thread caused by the absorption of sea water and variations in air humidity.

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[2] Colophonium cement was used for the adhesive.

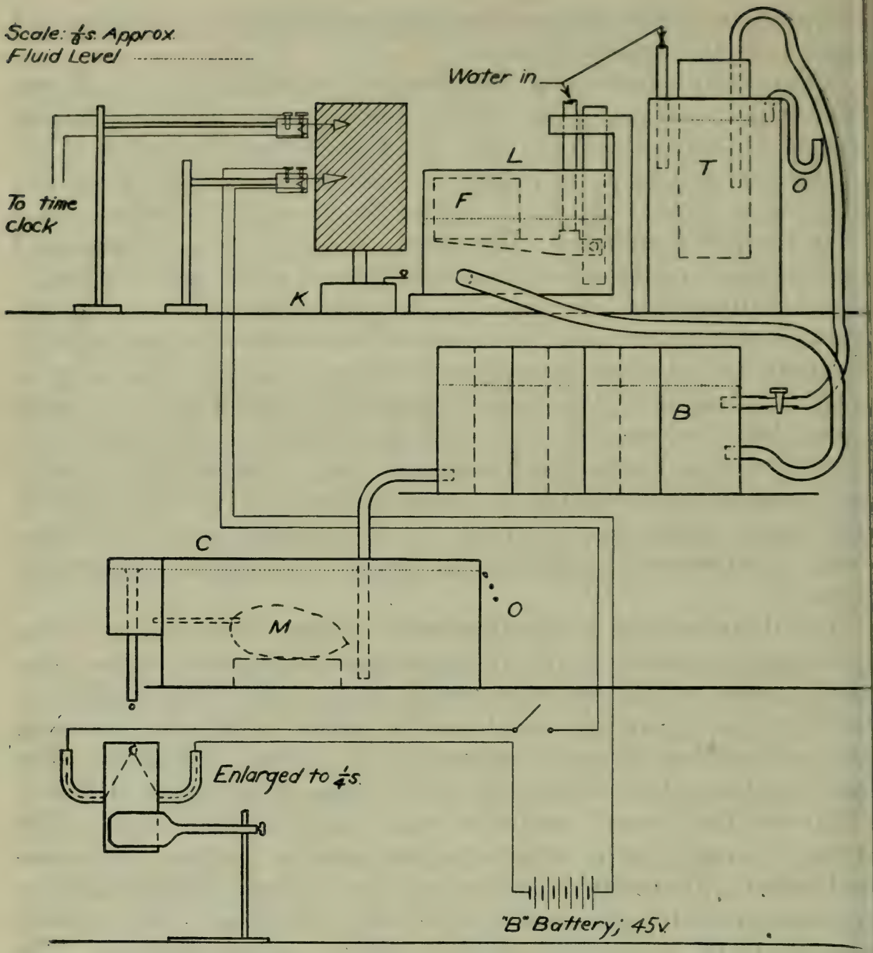

Figure 1.—Diagram of the set-up used in the drop-counting method. Oyster (M) placed in a constant-level tank (C) pumps the water into a small vessel attached to the wall (left side of tank). Through an overflow, drops fall between the two electrodes mounted in a glass tube (lower left side of the diagram) and complete the circuit from a 45-volt, B battery. Signals are recorded by one of the magnets on the drum of a kymograph (K). The delivery of sea water to tank (C) is regulated by a constant-level tank (L) in which the lower end of a supply pipe is opened or closed by a lever operated by means of a float (F). The water is delivered first to a mixing chamber (B) from which it runs into tank (C) and overflows over the side (O). The floating vessel (T) contains the solution which is delivered to the mixing chamber (B) at a constant rate controlled by a head pressure. As the amount of liquid in vessel (T) diminishes the container rises and the level of liquid remains constant. The lower part of the siphon, shown in dotted lines, is flexible. O is an overflow. In order to equalize the temperature of the solution, which is being delivered to the mixing chamber, the vessel (T) is kept in running sea water.

Before placing the oyster in the tank the levels in both large and small vessels (fig. 2, C and O) are carefully adjusted so that no water enters the small vessel while it circulates freely in the large one. The rate of flow through the large vessel is adjusted to about twice the maximum rate of pumping of the oyster at a given temperature. Water discharged by the oyster and overflowing from a small vessel is collected in a dumping chamber (fig. 2), the capacity of which may be adjusted to the conditions of the experiment. It was found that with a slow-motion kymograph the volume of the dumping vessel should be about 200 ml. For faster movement vessels from 30 to 50 ml. were employed.

The dumping chamber consists of a rectangular or vase-shaped container (D) mounted slightly eccentrically on the horizontal axis and kept in position by means of a catch (A) released by a float (F) when water reaches the desired level. In turning over, the vessel touches the string of a lever which makes a vertical mark on the kymograph drum (K). To insure the return of the vessel to its proper position, a counter-weight may be attached to its lower part. The water is supplied at a desired rate from a jar (L) in which the water level is controlled by means of a lever and a float (F)[3]. The solution to be tested is delivered from a jar (T) floating in a tank filled with water. In this way constant head pressure and a desired rate of flow of water are maintained. From the supply jar (T) the solution enters the mixing chamber (B) built according to the suggestion made by Hopkins (1931). By regulating the rate of flow of sea water and the rate of the delivery of the experimental solution the desired dilution can be maintained for a reasonably long time.

Other details of the set-up developed in my laboratory since 1936 are given in figure 2 and require no further explanation. Many control experiments carried out during the last decade show that oysters wrapped in rubber aprons and placed in a constant level tank suffer no ill effects and continue their normal activity for many days and even weeks. Results of one of the control experiments are summarized in table 1 which shows no significant changes in the rate of pumping at the end of the fifth day. Figure 3 represents part of a record obtained by this method and shows that under the experimental conditions the oyster is able to maintain for several hours a steady rate of pumping.

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[3] I am grateful to Dr. V. L. Loosanoff for the suggestion to adopt a design of a common flushing gadget used in home plumbing to control the head pressure in the delivery tank.

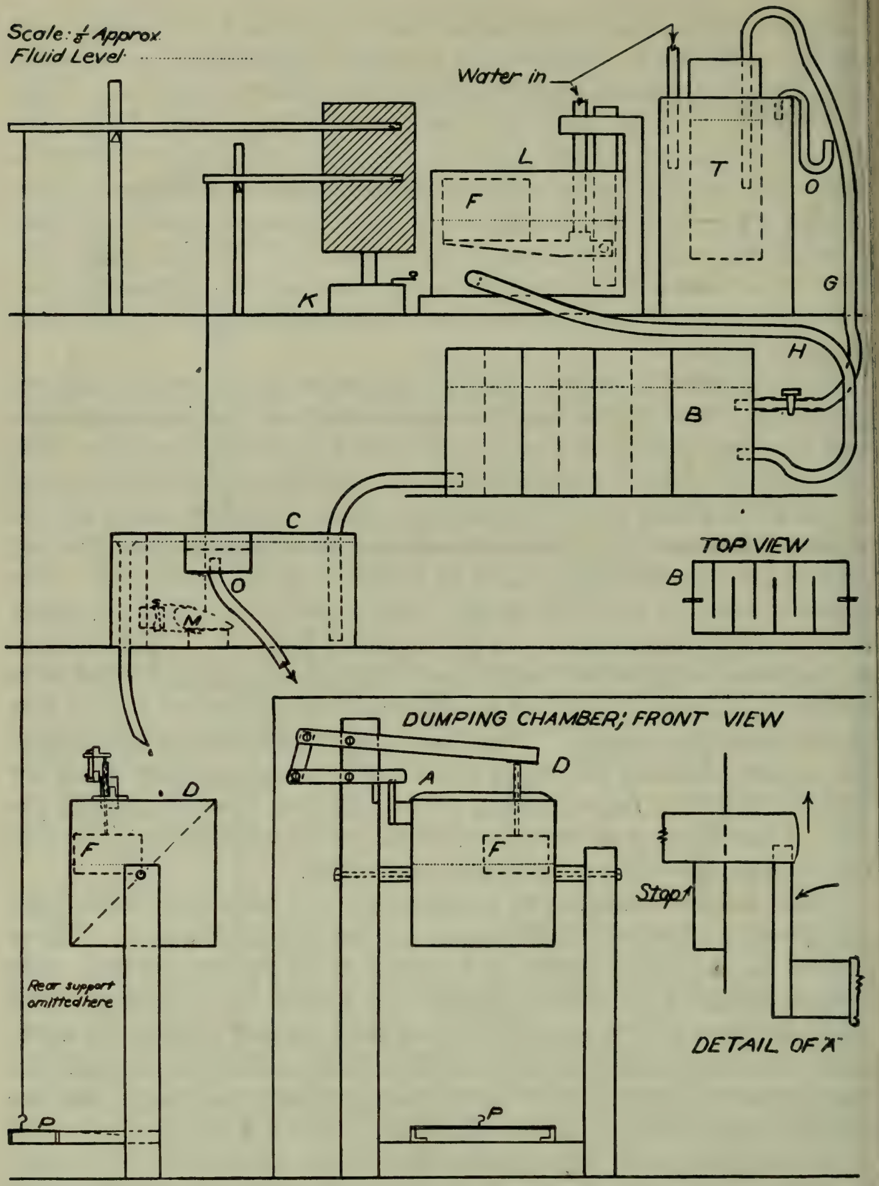


Figure 2.—Diagram of set-up used in the "apron" method of recording rate of pumping of water by the oyster. Constant-level tank (C) with oyster (M); constant-level tank (L) regulating the flow of sea water; float (F); mixing chamber (B); kymograph (K): floating vessel (T) from which the solution is delivered to the mixing chamber; delivery tube (G) leading from vessel (T) to the mixing chamber; tube (H) for the delivery of sea water; overflow (O). The lower part of the diagram shows dumping vessel (D) (side view at the left and front view at right). The float (F) pushes the lever and releases the catch (A); (detail of the construction of catch is shown at the right lower corner of the diagram). Platform (P) with hook for a thread leading to the writing lever. All parts are made of plastocoele.

TABLE 1.—*Rate of pumping of water by an adult oyster during the first and fifth day of continuous observations (July 1937)*

Day	First half of a day from 8 a. m. to 8 p. m.				Second half of a day from 8 p. m. to 8 a. m.				Mean for day, liters per hour
	Liters, total	Rate, liters per hour	Hours open	Temperature range, ° C.	Liters, total	Rate, liters per hour	Hours open	Temperature range, ° C.	
First	60.0	5.0	12	21.2–21.8	85.6	7.13	12	21.2–21.8	6.06
Fifth	67.6	5.36	10.2	19.5–20.0	77.6	6.47	11.2	19.8–20.0	5.9

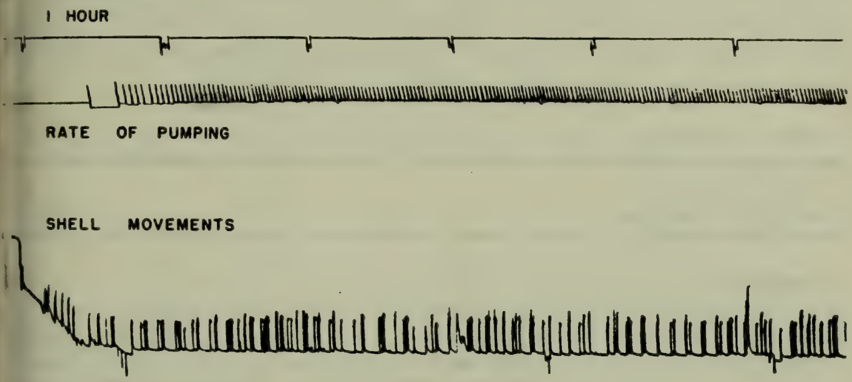


FIGURE 3.—Simultaneous record of the rate of pumping (second line) and of shell movements (third line) obtained from the set-up shown in figure 2. Each upward stroke on the second line represents a discharge of 249 ml. of sea water. Temperature 21.2° C.

EFFECT OF FREE CHLORINE ON SHELL MOVEMENT

No disinfecting or cleansing solution can reach the body of a shellfish unless the valves are open and water has free access to the pallial cavity. It is therefore essential for the success of chlorination that oysters open their shells as soon as they are placed in a conditioning tank. The first step in the present experiments was, therefore, to determine the time elapsed between the placing of oysters in the sea water and the opening of their shells. Examination of hundreds of records accumulated during the course of investigations on the physiology of feeding conducted during the last 15 years provided the answer to this question. It was found that about 99 percent of adult oysters, which during the summer were kept overnight out of water at room temperatures varying from 18° to 25° C., opened their shells within less than half an hour after being returned to water of 18°–21° C. After a few rapid contractions, which may be attributed to the efforts to expel gases accumulated in the pallial cavity, the shell movement assumes normal rhythm. If the exposure is only of short duration, varying from 2 hours to several minutes, some of the oysters returned to the water may remain closed for several hours. So far, n definite correlation has been established between the length of th exposure and the duration of the lag period.

The experiment conducted in 1944 was designed to determin whether the exposure at high or low temperatures, which may be ofte encountered in the handling of oysters by commercial concerns, woul affect the time of their opening. Two oysters were placed in th refrigerator and kept for 24 hours at 5° C. and two specimens wer exposed for the same length of time at 30° C. in the incubator. Th four oysters opened immediately after being placed in water at abou 21°–22° C. but the shell movements of those exposed at 5° C. (fig. 4 were rather abnormal. In all four oysters, pumping started only o the third or fourth day after they were placed in water.

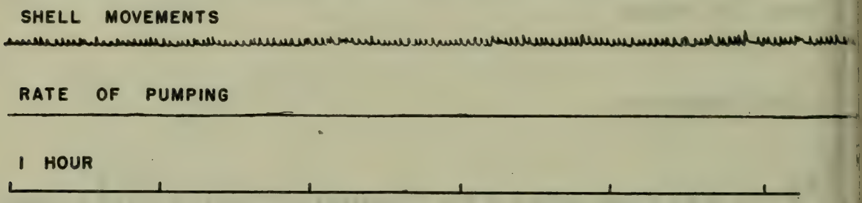
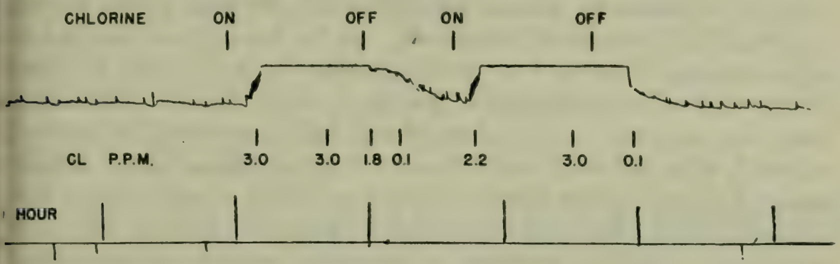


Figure 4.—Shell movements (upper line) and rate of pumping (second line) of th oyster after 24 hours of exposure at 5° C. Temperature of water 20°–21.5° C Compare with the normal shell movement shown in figure 5 (left half).

To determine the lowest concentration of free chlorine which woul cause the response of the adductor muscle, weak solutions of chlo ramine-B and calcium hypochlorite (HTH) were delivered at a know rate through a mixing chamber. Samples of water for chlorin determination were taken at regular intervals near the body of th oyster. Time elapsed between the moments the chlorine solutio was turned on and the desired concentration was established in th tank varied from 12 to 15 minutes. The first sample was alway taken at the first sign of muscular reaction, and subsequent samplin was continued at intervals corresponding to different phases o muscular curve until the shells were completely closed. The chlorin solution was turned off and the next sample was taken at th first sign of relaxation of the adductor muscle. A typical reaction to fairly high concentrations of chlorine varying from 2.2 t 3 p. p. m. is shown in figure 5. The reaction consists in a series o contractions producing on a kymograph record a typical "staircase' effect. Relaxation begins as soon as the addition of chlorinated wate is stopped and the concentration of free chlorine is reduced. A one can notice by comparing figures 5 and 6 both phases of the reaction, i.e., the contraction and the relaxation periods, repeat themselves with remarkable regularity regardless of the concentration sed. Thus, the response to concentrations varying from 0.01 to .02 p. p. m. shown in figure 6 are similar to that occurring in a much tronger concentration of about 3 p. p. m. (fig. 5). The "staircase" ffect which is frequently explained as being due to an increased iritability of the acting tissue (Lee, 1907; Lucas, 1917) may be atributed in this case to the neuro-muscular facilitation as the chemical timulus reaches more and more effectors. This condition may be imilar to that described by Pantin (1935) for the contraction of the phincter muscle of the sea anemone *Calliactis*.



IGURE 5.—Shell movement and rate of pumping of oyster in chlorinated water. Each downward stroke on the lower line represents a discharge of 223 ml. of sea water pumped by the oyster. High upward strokes on the lower line represent 1-hour intervals. Parts of the records showing "staircase" effect became blurred in reproducing but are clearly seen on the original records. Temperature 19.5° C.

The staircase effect is usually produced in laboratory experiments y electrical or mechanical stimuli of short duration applied to solated muscle at regular intervals. In our experiment, the whole rganism is subjected to a continuous chemical stimulation applied ith a gradually increasing intensity. It is known (Nelson, 1938; altsoff, 1938) that the oyster may restrict the access of water to a efinite section of the pallial aperture or may admit it through its ntire length. It is therefore possible that the irritating substance cts upon the increasing number of receptors as various parts of the antle and gills come in contact with the chemical. Whether this xplanation is correct requires further physiological studies which are eyond the scope of the present investigation.

Experiments conducted in my laboratory in connection with other udies show that the staircase response can also be provoked by sing a great variety of inorganic and organic compounds, such for stance as mineral salts, acids, or adrenalin, and occurs also sponaneously (fig. 7) in normally feeding oysters. Staircase contractions ading to a complete closure of the shell develop also in oysters kept r several hours in a small volume of water. The closing of the shell this case may be attributed to the accumulation of CO_2 and other roducts of metabolism. The response of the adductor muscle to free chlorine is, therefore, not specific but represents the usual reaction o the oyster to chemical stimulation.

The question arises whether the response of the adductor muscl could be correlated with the intensity of the stimulus, i. e., with th concentration of free chlorine. In several instances, the concentra tion of 0.02 p. p. m. was effective in inducing complete closure o shells (fig. 6) while, in other instances, greater concentrations cause but insignificant changes in muscular rhythm (fig. 8). This lack o correlation between the intensity of the stimulus and the degree o response is primarily due to the increased tolerance which develop as a result of subsequent treatments. It has been found that the firs administration even of very weak solution (0.02 p. p. m.) is usuall effective in inducing complete closing of shells (fig. 6). Subsequen doses are, however, easily tolerated and full response of the adducto muscle is attained only when the concentration is increased almost hundred times. A case illustrating this condition is presented in figur 6 showing that after initial stimulation with 0.02 p. p. m. of chlorin there was a marked increase in tolerance and the concentration c 0.8 p. p. m. caused only partial response. Complete closure (nc shown in fig. 6) occurred when concentration was increased to 1. p. p. m. An extreme case of high tolerance was recorded in the exper ment shown in figure 9 when the oyster treated by gradually increase doses remained open in the concentration as high as 1.80 p. p. m. N difference in the response of the adductor muscle was noticed whe HTH instead of chloramin-B was used.

From the studies of the effect of free chlorine on shell movement c oysters the following inferences can be made: (1) Oysters respond t

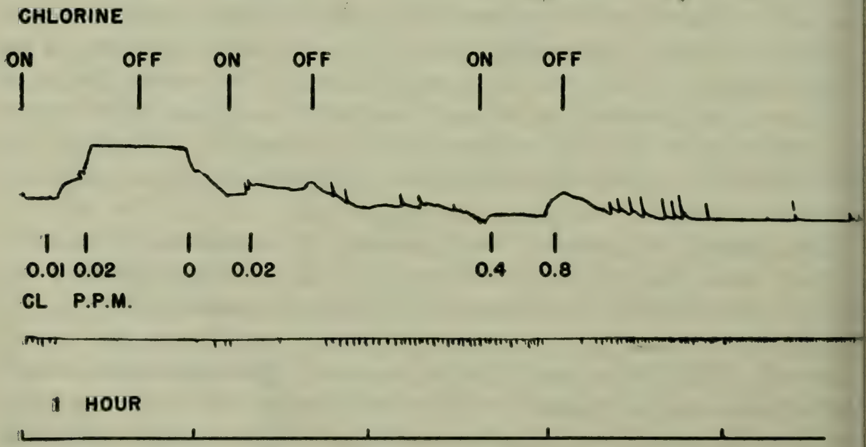


Figure 6.—Effect of free chlorine on the shell movement (upper line) and ra of pumping (middle line) of the oyster. Each stroke represents the dischar of 223 ml. of sea water pumped by the oyster. Temperature 21.4° C.

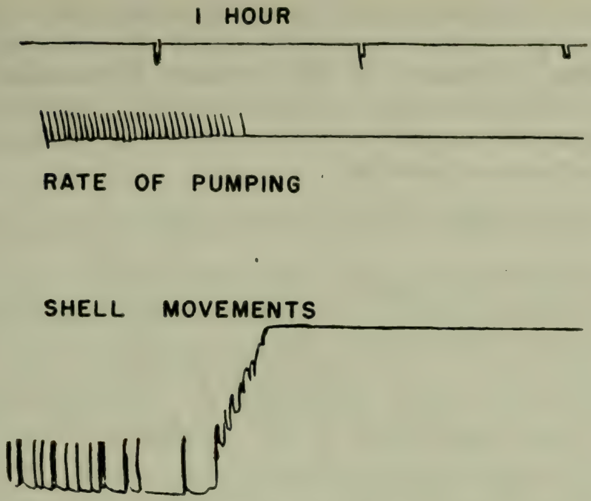


Figure 7.—Record of the "staircase" effect or "treppe" developed spontaneously in the oyster kept in running sea water. Each upward stroke of the middle line represents a discharge of 249 ml. of sea water. Temperature 21.2° C.

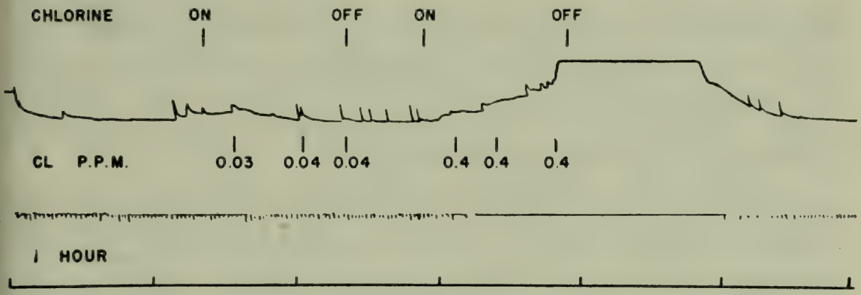


Figure 8.—Effect of free chlorine on the shell movements (upper line) and rate of pumping of water (middle line). Each stroke represents a discharge of 223 ml. of sea water. Temperature 21.4° C.

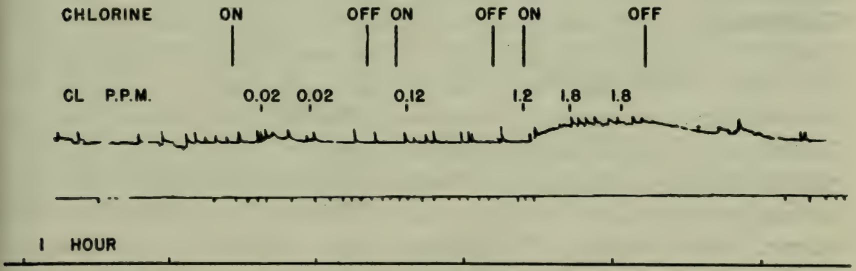


Figure 9.—Effect of free chlorine on shell movements (upper line) and rate of pumping of water (lower line). Each stroke represents a discharge of 223 ml. of sea water. Temperature 21.4° C.

the presence of 0.01 p. p. m. of free chlorine and some of them would completely close at this low concentration; (2) tolerance easily develops by preceding treatments; (3) the presence of free chlorine in concentrations from 0.01 to 3.0 p. p. m. causes no irreparable injury to the adductor system, and the muscle relaxes as soon as the residual chlorine in the water is reduced.

EFFECT OF CHLORINE ON THE PUMPING MECHANISM OF THE GILL

The principal factors involved in the maintenance of a steady current of water through the gills are the beat frequency of the lateral cilia, the energy of their effective strokes, and the synchronization of the ciliary motion. It is clear that the decrease in the beat frequency or in the effectiveness of the stroke must result in a decrease in the rate of current. Direct observation of the disturbance in the rhythm of ciliary motion along the different filaments of an intact gill is impossible but nevertheless the results of such a disturbance are apparent through the loss of hydrostatic pressure inside the water tubes and decrease or stoppage of the efferent water current (Galtsoff, 1928). The disturbance in the ciliary motion of the excised pieces of gill tissue can be, however, easily seen under the microscope. In such preparations, changes in the magnitude of the strokes and in the rhythm of the lateral cilia can be provoked by tapping and by chemical stimulation. This disturbance in synchronization of the ciliary motion cannot be studied quantitatively but the beat frequencies may be accurately determined by a stroboscope technique.

The excised pieces survive in sea water for more than 24 hours and for at least 12 hours maintain a steady rate of ciliary motion. For testing the effect of chlorine, the sea water in the microaquarium was replaced by chlorinated sea water delivered by means of a fine pipette. To avoid dilution with the water adhering to the tissues, three changes were made before the preparation was sealed. Chlorine concentrations in sea water, recorded in these experiments, are those which were determined in freshly made solutions just before they were used. Undoubtedly, there was some loss of free chlorine due to the manipulation of the liquid and the presence of mucus and blood discharged from the gills. The small volume of liquid used was not sufficient for determining the concentration of available chlorine in the preparation. On the other hand, it has been found impractical to keep small pieces of gills in running water because under these conditions their longevity is greatly reduced, probably because of the leaching of blood from the tissues. Furthermore, gill filaments could not be kept in a desired position in running water, which turns them around. It has already been mentioned that because of the variability in the beat frequencies in different rows of cells, observations should be made on the same band of lateral cilia.

The beat frequencies, shown in number of beats per second, have been computed from direct readings of a strobotac graduated in the numbers of oscillations (in hundreds) per minute. The frequency of 10 per second (600 of the strobotac scale) is the lowest that can be read on the dial of this instrument and all the readings below that figure are marked >10. Since the slowing down of the cilia is usually accompanied by considerable arrhythmia, it was impossible to determine the number of beats by using the multiple frequencies of the strobotac, which would bring an oscillating movement to an apparent standstill. Efforts were made to make a group of 10 readings each at 1-minute intervals, but sometimes two or more minutes elapsed before the locus under observation could be found and focused.

The results presented in a condensed form in table 2 are arranged in chronological order. The first column of the table shows the initial concentration of free chlorine in the sea water used. Each entry in this column indicates that the solution has been changed while the mark (1) denotes that a second series of readings was made without changing the solution.

It is clear from examination of the table that the concentration of 0.02–0.03 p. p. m. may materially reduce the beat frequencies. The response is, however, of a temporary nature, probably because of the chlorine demand of the preparation containing mucus, blood, and other organic material. Tolerance develops rapidly and a second dose of low concentration (experiment, February 28) produces no appreciable effect. In concentrations of about 1 p. p. m. the beat frequencies may be reduced to less than 10 per second. Complete cessation of ciliary motion takes place only at the concentration of about 22 p. p. m. High resistance of the preparation in the experiment of March 3 may be associated with an unusually copious discharge of mucus by the gills. Irreparable changes in the lateral cilia were recorded after 10 minutes exposure to the concentration of 22.5 p. p. m. (experiment of March 2 and 3) and the recovery after the return to unchlorinated sea water was only partial. It is interesting to note that in both cases the frontal cilia continued to beat, even at this high concentration.

The presence of chlorine causes noticeable increase in the variability of the beat frequencies (table 2, column 6) and leads to arrhythmia easily discernible with a strobotac.

TABLE 2.—*Effect of free chlorine on beat frequencies of lateral cilia of the oys*
(Ostrea virginica)

Chlorine, p. p. m.	Time	Temperature, °C.	Beats per second, mean	Standard deviation	Coefficient variation	Beats per second, range	Number of readings	Remarks
Experiment, Feb. 28, 1945:								
0	12.00–12.09	21.6	18.2	0.2	1.1	17.9–18.6	10	
0.02	12.10–12.24	21.3	10	-------	-------	-----------	------	
(1)	1.45– 1.54	22.0	18.5	.6	3.2	17.5–19.0	10	
0.02 [2]	1.55– 2.17	22.0	17.9	.4	2.1	17.5–18.3	10	
0.2	2.18– 3.03	22.0	>10	-------	-------	-----------	10	
1.5	3.04– 3.17	22.0	>10	-------	-------	-----------	10	
(1)	3.18	--------	13.0	-------	-------	-----------	5	Arrhythmia.
Experiment Mar. 2–3, 1945:								
0	11.40–12.55	21.9	18.2	1.8	9.8	15.5–20.2	10	
0.03	1.08– 2.03	21.9	>10.0	-------	-------	-----------	10	
(1)	3.05	21.9	15.3	-------	-------	-----------	5	
0.4	3.10– 3.12	22.1	17.0	-------	-------	17.0	2	Arrhythmia.
(1)	3.45– 4.10	22.1	>10.0	-------	-------	-----------	2	Do.
1.5	4.20– 4.40	22.1	>10.0	-------	-------	-----------	2	Copious charge of r cus.
0 [3]	9.25–10.10	22.2	12	-------	-------	12.0	5	Partial recove
22.5	10.15–10.25	22.2	0	-------	-------	-----------	------	Frontal cilia.
0 [3]	10.26–11.30	22.1	>10	-------	-------	-----------	15	Beating irregu
Experiment Mar. 3, 1945:								
0	11.45–11.55	23.9	19.1	.8	4.1	17.7–20.2	11	
3.0	12.01–12.11	24.2	15.6	1.6	10.3	13.8–18.8	10	Copious charge of m cus.
(1)	1.18– 1.28	23.8	15.5	.3	1.8	15.3–16.2	11	
22.5	1.29– 1.40	23.8	0	-------	-------	-----------	------	Frontal c beating.
0	1.41– 4.20	24.2	>10	-------	-------	-----------	20	
(1)	4.25	25.1	11.3	-------	-------	-----------	5	

[1] A second series of readings was made without changing the solution.
[2] Second dose.
[3] Water changed.

DROP-COUNTING METHOD

The effect of free chlorine on the intact gill was determined by er ploying the drop-counting technique. Experiments were perform both with chloramine-B and HTH solutions in sea water of 31°–3 salinity and at temperatures varying from 22.3° to 24.5° C.

In conducting these experiments the oysters were kept for th first 15 or 20 minutes in the untreated sea water. During this tim the number of drops of water discharged through the cloaca w determined by obtaining a 10-second record for each consecuti minute (fig. 10). After the chlorinated water was turned on, th kymograph was run continuously until the discharge of the wat by the oyster stopped. During this time, samples of water we taken at frequent intervals for chlorine determination. The rate the discharge of water, in number of drops per 10 seconds, is present graphically in figures 11 and 12. In all the experiments the conce tration of 0.01 p. p. m. caused either a complete cessation of wat discharge or at least materially reduced its rate. Recovery was rap and complete. In several instances the rate of pumping after th

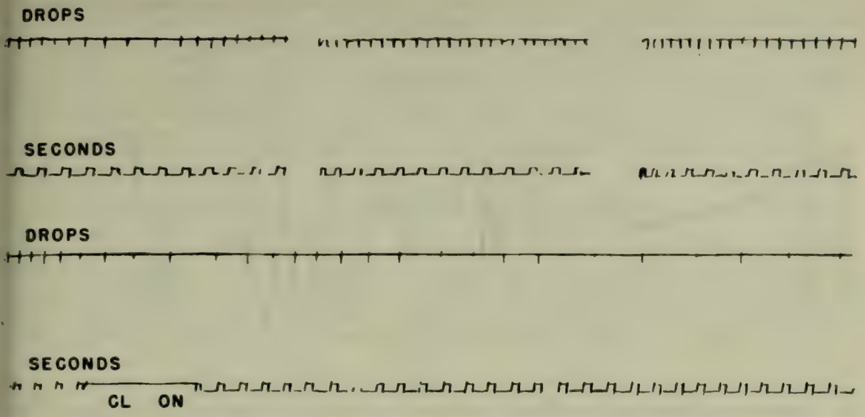


FIGURE 10.—Records of the rate of pumping obtained with a drop-counting method. Temperature 22.7° C.

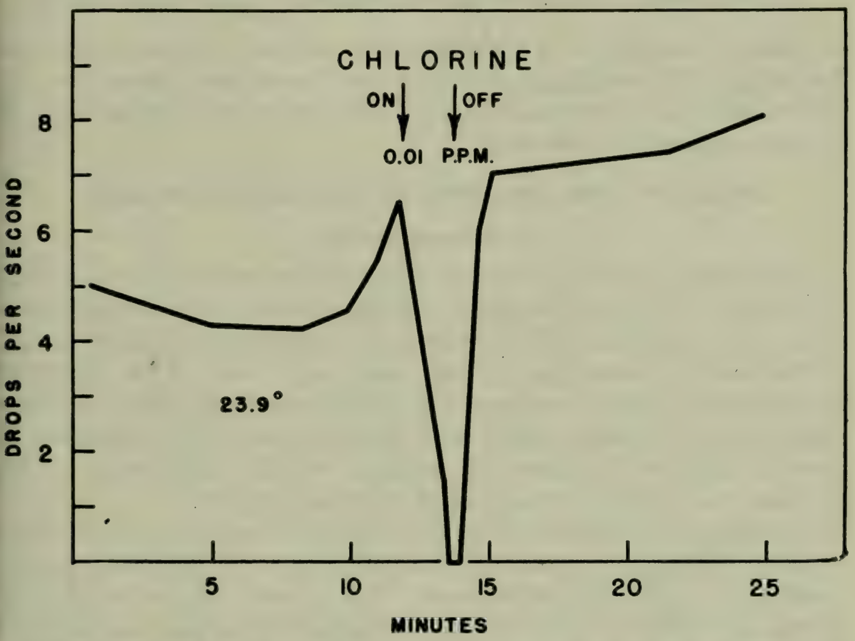


FIGURE 11.—Effect of the first treatment with 0.01 p. p. m. concentration of chlorine on the rate of pumping (drop-counting method). Temperature 23.9° C.

chlorine treatment was even higher than before. Increased tolerance persisted in some cases for 2 hours after the first treatment and the response to the second dose of chlorine was considerably delayed (fig. 12).

Since the stroboscope observations show that low concentrations

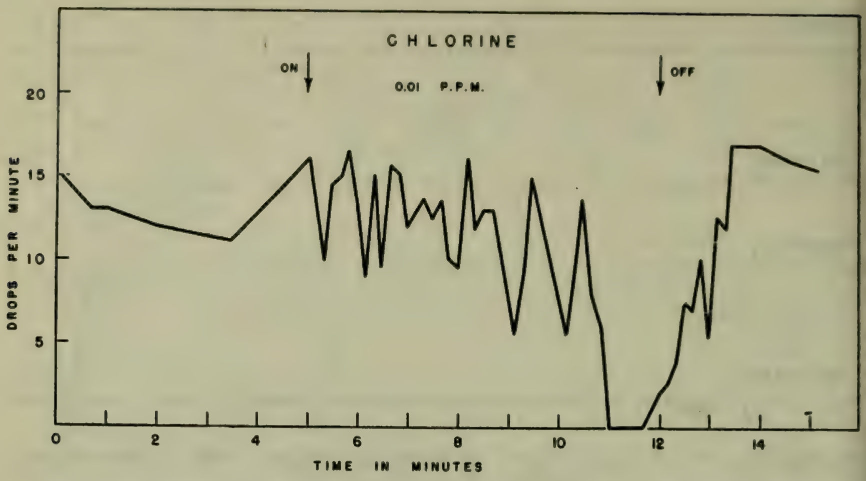


FIGURE 12.—Effect of the second treatment with 0.01 p. p. m. concentration of chlorine applied 2 hours after the first treatment. Temperature 23.9° C.

of chlorine used in these experiments do not stop the beating of the lateral cilia the cessation of current may have been due to the disturbances in the coordination and in the rhythm of ciliary motion, or to the contraction of the ostia.

EFFECT OF FREE CHLORINE ON THE RATE OF PUMPING

The Apron Method

The rate of pumping of water by an intact organism was studied by means of the apron technique. Numerous observations performed since 1936 in the Woods Hole, Mass., and Yorktown, Va., laboratories of the Service show that oysters may keep their shells open and display normal shell movement while their pumping mechanism is not functioning. Hopkins (1933) was the first one to call attention to this condition in *O. gigas* and pointed out the significance of the pallium in controlling the access of water to the gills.

The rows of tentacles along the edges of the mantle provide an efficient and highly sensitive mechanism capable of detecting minute quantities of irritating substances. As tentacles easily respond to chemical stimulation, it is reasonable to assume that chemical receptors are located on or near them. The response to a chemical stimulus usually follows the following pattern: contraction of the tentacle, contraction of the edge of the mantle, and contraction of the adductor muscle (Hopkins, 1932; Galtsoff, 1940). If stimulus is weak, only the first response takes place; in case of more effective stimulation all three responses follow one another with different lag periods, although the middle one, i. e., the contraction of the radial muscles of the pallium is sometimes omitted.

If the conditions of the environment remain constant, oysters are capable of maintaining a steady rate of pumping for many hours and even days. Figure 3, illustrating this point, represents one of the many records obtained in the Woods Hole laboratory. In this particular case pumping continued for several hours at the rate varying from 8 to 10.5 liters per hour.

As soon as chlorinated water is turned on and even before the concentration of free chlorine can be detected by the o-tolidine test the rate of pumping slows down. In many instances the concentrations of 0.01–0.02 p. p. m. caused complete cessation of pumping, which was resumed when free chlorine was removed (figs. 13, 14, 15).

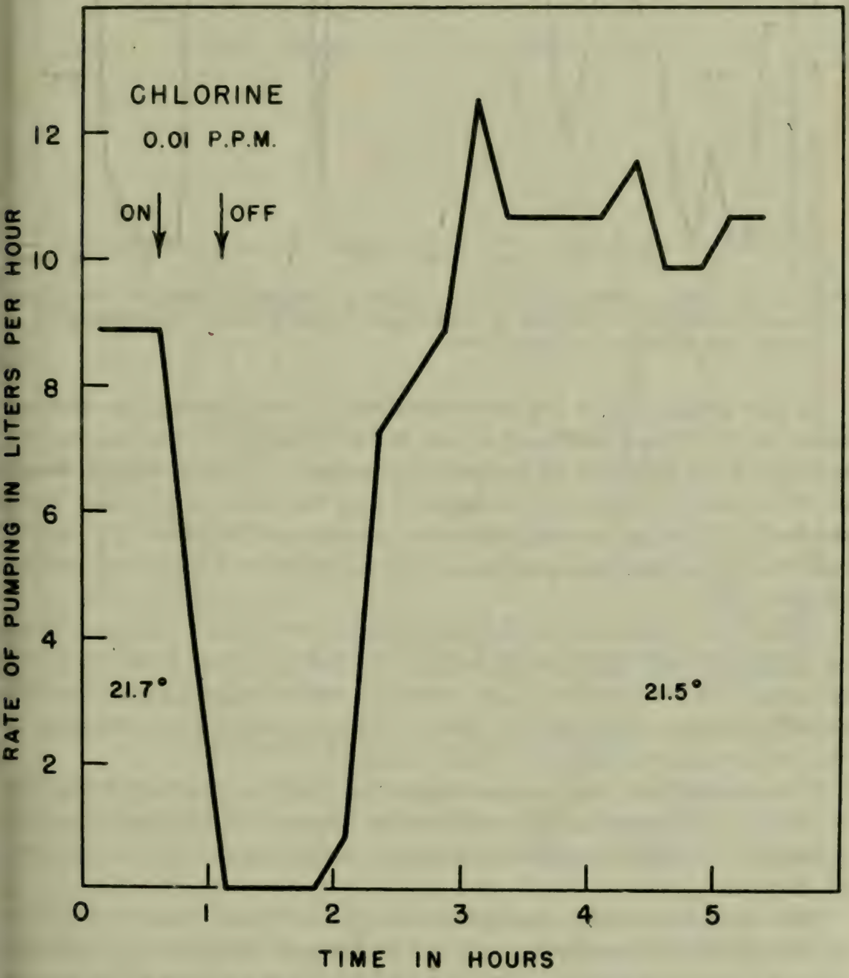


FIGURE 13.—Effect of 0.01 p. p. m. of chlorine on the rate of pumping of water by the oyster (apron method). First treatment.

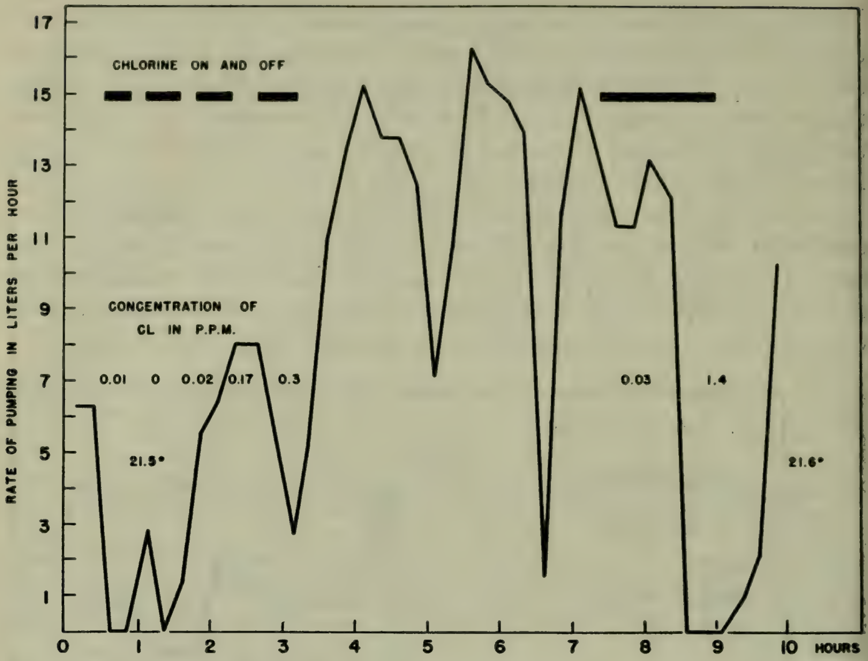


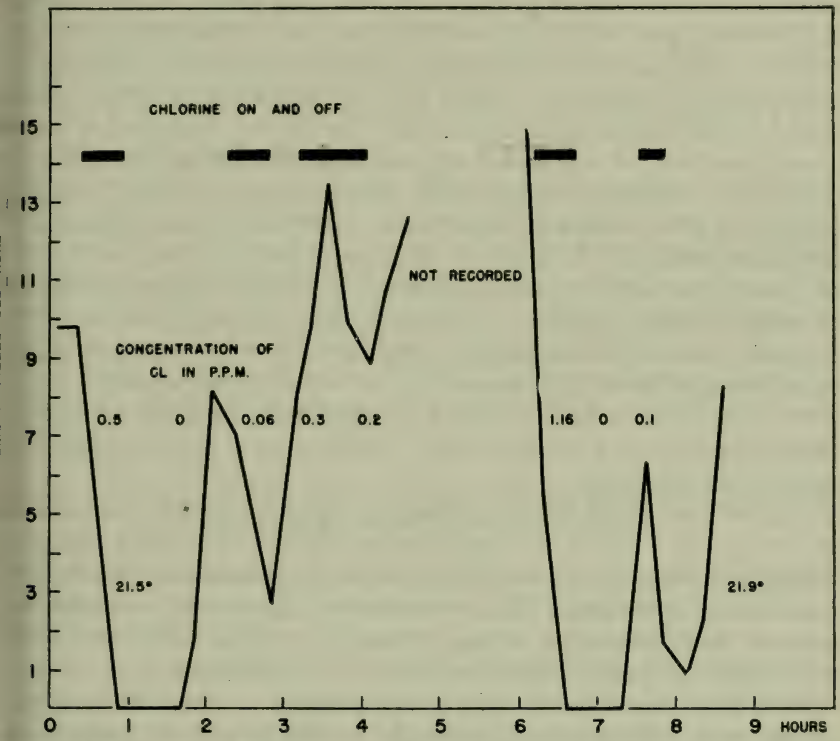
Figure 14.—Effect of free chlorine on the rate of pumping of water by the oyster (apron technique). Periods of treatments with various concentrations of chlorine are indicated by black bars.

In the presence of a low concentration of free chlorine the slowing down of the rate of pumping occurs before significant changes may be noticed in the behavior of the adductor muscle. This is clearly shown in the records reproduced in figure 8 and was true in all other cases studied. Stimulation with high concentrations of chlorine (3 p. p. m.) results in an immediate contraction of the adductor muscle and closing of the valves.

Under the conditions of the experiments the desired concentrations of chlorine were maintained for the periods varying from 20 to 90 minutes. It was noticed that pumping was resumed soon after the chlorinated water was turned off and the concentration of chlorine in the water surrounding the oyster reduced.

Treatments with the concentrations of chlorine varying from 0.01 to 3.0 p. p. m. cause no injury to oyster tissues and the normal rate of pumping is usually established within a short time after the removal of chlorine.

Repeated treatments cause considerable decrease in the sensitivity of the oyster and pumping may be continued, although at a greatly reduced rate, at the concentrations which were effective in stopping it during the first test. Under the conditions of the experiments, some of the oysters repeatedly treated with chlorinated water were noticed to produce a slow current in the concentrations of about 1. p. p. m. This is probably the highest limit of tolerance of an intact organism. It is of interest to point out that in excised pieces of gill tissue the beating of the lateral cilia is stopped by a concentration of about 22 p. p. m. An inference can be drawn from these observations that an intact organism is much more sensitive to free chlorine than its separated parts.



IGURE 15.—Effect of free chlorine on the rate of pumping of water by the oyster (apron technique). Periods of treatments with various concentrations of chlorine are indicated by black bars.

VARIATIONS IN STIMULUS THRESHOLD

It has been shown that successive treatments with chlorinated water increase the tolerance to such an extent that oysters may function normally in the concentrations which, when applied for the first time, caused complete suppression of pumping and closing of shells. Experiments conducted in August–September 1945, at Woods Hole, showed that threshold sensitivity varies, apparently depending on the condition of the organism. As in the previous summer 4- or 5-year-old oysters from Narragansett Bay, kept for at least 2 weeks in

Woods Hole Harbor, were used. In many instances they failed t react when subjected to the concentration of chlorine varying fro 0.01 to 0.03 p. p. m. (fig. 16). At 0.05 p. p. m., irregularity of muscular behavior was noticed followed by a copious discharge of mucu "Staircase" effect (fig. 16) and cessation of pumping was noticed onl when concentration of about 10.2 p. p. m. was reached. Experiment were repeated also with Long Island Sound oysters which were use immediately upon receiving them at Woods Hole and previous t experiments were not subjected to Woods Hole water. They reacte in the same way as Naragansett Bay oysters. The only noticeabl difference between the conditions of the experiments conducted i 1944 and 1945 was in the quality of the sea water used in the laboratory. It was noticed that in 1945 the water contained a muc greater amount of suspended organic matter from domestic sewag than in the previous summer and that its nitrite content was hig enough to give persistent interference with the Cl-determination b o-tolidine method. It appears quite possible that lower sensitivit of oysters was somehow associated with the increased sewage pollutio of water. This problem is of considerable interest because of th common practice of discharging large amounts of untreated or chlorinated sewage directly into coastal waters where it may come in contac with oyster beds. It is planned to study this problem on a comprehensive scale in a locality where conditions are most favorable fo such an investigation.

Oysters used in the 1945 experiments showed general low sensitivit and failed to respond to slight tapping, touch, and other forms o mechanical stimulation which in previous experiments usually provoked strong response. There was nothing, however, in the appearance of these oysters or in the type of their shell movement whic would have indicated that they were sick or weakened.

In view of these observations it is impossible to establish the lowes concentration of chlorine physiologically effective at all times for al the oysters. We are justified, however, to state that the range of thi concentration lies between 0.01 and 0.6 p. p. m.

PROTECTION AGAINST IRRITATING SUBSTANCES

Oysters kept in chlorinated water secrete large quantities of mucu which is usually discharged as pseudo-feces from the mantle cavity a smaller amount of mucus is also discarded through the cloaca an can be found with the true feces. The secretion of mucus wa especially pronounced in the oysters of low sensitivity. In some o the 1945 experiments as much as 30 ml. of mucus, discharged by single oyster, accumulated on the bottom of a tank in 24 hours Mucus secreted by the mantle and the gills serves as a protectiv coating for delicate tissues of the tentacles, mantle, and gills, and absorbs chlorine before it comes in direct contact with the neuroreceptors. There is a considerable loss of chlorine when the water is passed through the oyster gills. This fact was demonstrated by my earlier experiments (Galtsoff, 1925, unpublished data of the former U. S. Bureau of Fisheries) in which the water that passed through the gills was collected by means of a rubber tube inserted into the cloaca (Galtsoff, 1926). Excerpts from one of these experiments are presented in table 3.

It is of interest that no chlorine could be detected in the discharged water when the concentration in the tank was 0.5 p. p. m. Presumably, it was completely removed by organic matter of the tissues of the gills. In higher concentrations there was a corresponding loss of chlorine in the discharged water.

Furthermore, the experiments show that the pumping mechanism of the gill is much less sensitive to free chlorine than the more delicate mantle and the adductor muscle; if the functioning of this controlling mechanism is prevented by inserting a wedge between the shells, keeping the valves apart, the lateral cilia continue to produce current and even get adapted to the concentrations as high as 1.8 p. p. m. These data are fully in accord with the observation on the rate of beating of the excised lateral cilia in various concentrations of chlorine.

EFFECT OF UNINTERRUPTED CHLORINATION ON MUSCULAR ACTIVITY AND CILIARY MOTION OF THE GILLS

In the experiments described, conducted in the summer of 1945, the duration of treatment at a given concentration of chlorine did not exceed 90 minutes. In many instances it was much shorter. The question naturally arises whether long exposure to initial concentration which provokes strong reaction, would result in adaptation and changes in the behavior. Technical difficulties in maintaining constant concentration of chlorine in running sea water for several hours could not be overcome with the facilities available at the Woods Hole laboratory. In the experiments described below oysters were placed in tanks of about 10-liter capacity filled with sea water which was stirred by an electric agitator and chlorinated by adding chloramine-B solution. The desired concentration of chlorine was attained within a few seconds. By frequent sampling, the changes in chlorine concentration were determined and, if necessary, additional amounts of chloramine solution were added. Shell movements were recorded in the usual way; presence or absence of cloacal current was ascertained by adding a drop or two of carmine suspension.

TABLE 3.—*Effect of chlorine on rate of pumping, drop counting method, Oct. 15, 192*

[Temperature 21.0°–23.5° C.]

Time	Rate of pumping, ml. per hour		Free chlorine, parts per million		Number o readings
	Range	Average	In tank	In discharged water	
1.38–1.45	1,714–2,400	2,000	0	0	
1.51–2.04	545–923	679	0.5	0	
2.08–2.44	207–324	255	1.0	0.7	
2.49–3.41	122–240	168	1.5	.9	
3.45–4.21	125–600	226	1.2	.9	
4.30–4.59	103		1.8	.7	
Next day [1]					
2.29–2.35	1,500–2,000	1,840	1.8	.7	

[1] Left overnight in chlorinated water.

These experiments, summarized in table 4, show considerable variation in the behavior of individual oysters in various concentrations o chlorine. It is, however, noticeable that in all of the experiment there was some disturbance in the maintenance of the cloacal current In some instances, when chlorine concentration did not exceed 0.0 p. p. m. (experiment A, table 4, fig. 16) shell movements were no affected. In other cases involving continuing treatment with concentration of about 0.5 to 0.6 p. p. m. (experiment E, fig. 16) oyster made periodical attempts to open slightly. Each opening was followe by a series of contractions which ended by a complete closing of th valves. The "staircase" effect was clearly noticeable in each case.

TABLE 4.—*Effect of uninterrupted chlorination in standing water on shell movem and ciliary motion of the gills*

[Concentrations of chlorine in each experiment are written in order of the occurrence]

Experiment	Duration of experiment, hours	Temperature, °C.	Chlorine, p. p. m.	Shell movement	Cloacal current
A	2	22.1–23.5	0	Normal	Strong.
	2½	22.1–23.5	0.03	Slight increase in number of contractions.	Decreased.
	7	20.1–22.0	0.03–0.05	do	Do.
B	12	22.0–24.1	0.03–0.05	Almost normal	Frequently interrupte irregular.
C	7	22.5–24.6	0.2–0.6–0.3	Increased number of contractions, periodical closures.	Irregular, frequently i terrupted. No curre at 0.06 p. p. m.
D	7	22.0–21.5	0.1–0.2	Open slightly, most of the time closed.	Stopped.
E	24	22.5–24.5	0.5–0.6	"Staircase" effect at irregular intervals.	Do.
	36	23.0–25.0	0.5–0.0	Closed	Absent.
F	6	24.0–25.5	0.4–0.5	No apparent effect	Irregular.
G	24	22.0–23.0	1.2	Closed	Absent.
H	48	21.5–25.0	0.8–0.9	do	Do.
I	24	21.5–25.0	0.6–0.2–0.8	Periodical "staircase" effect; later normal.	Irregular or absent.

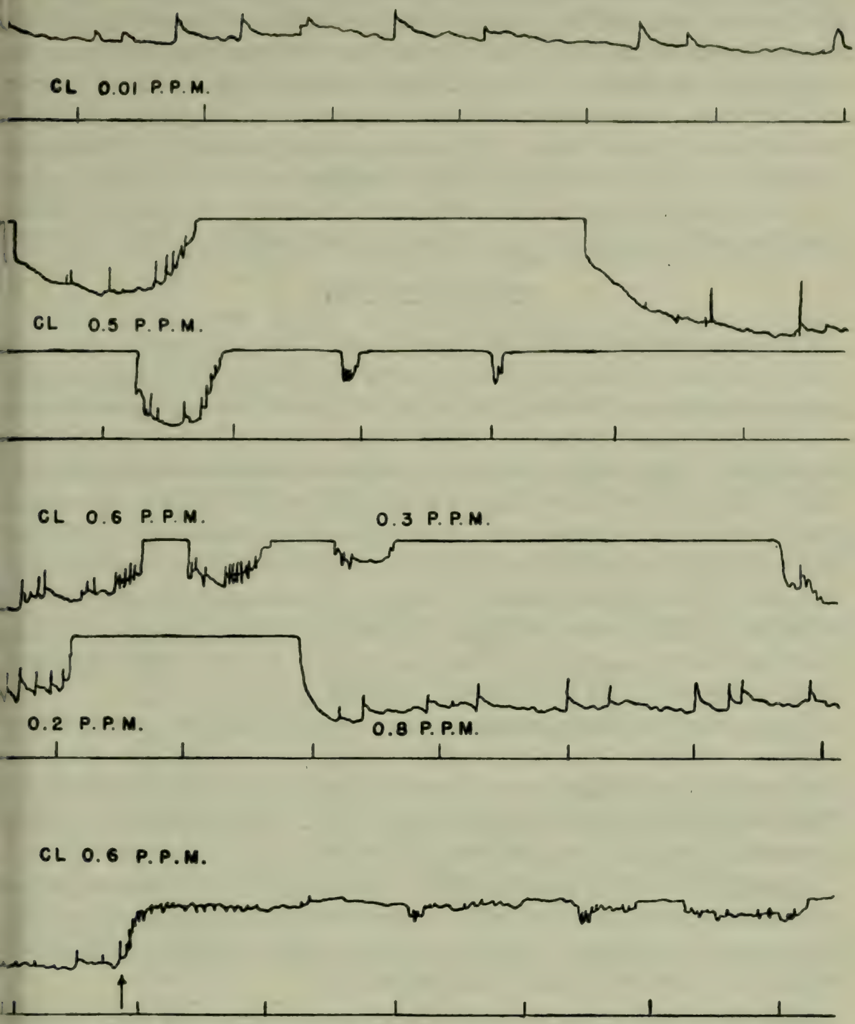


Figure 16.—Kymograph tracings of shell movements of oysters in various concentrations of free chlorine (summer 1945). Water not renewed during the experiments; sensitivity of these oysters was lower than those used in 1944. First tracing (single line), normal shell movement in 0.01 p. p. m. of chlorine; cloacal current slightly decreased. Second tracing (two lines), "staircase" effect in concentration of 0.5 p. p. m.; cloacal current irregular. Third tracing (two lines), abnormal shell movements in concentrations varying from 0.2 to 0.6 p. p. m.; normal shell movement at 0.8 p. p. m. is indicative of higher tolerance developed as a result of preceding treatments; cloacal current at the end of the experiment often stops. Fourth tracing (single line), "staircase" effect and attempts to open shells at the concentration of 0.6 p. p. m. No cloacal current. Straight line with vertical marks under each group indicates 1-hour intervals.

From observations on the behavior of individual oysters kept in chlorinated and unchanged water for periods of time varying from several hours to 2 days an inference can be made that in concentrations of less than 1 p. p. m. some oysters may eventually open and begin to pump water; the pumping may be irregular and much weaker than in pure water. Periodic opening followed by irregular and slight contractions (fig. 16) may be interpreted as an attempt to test the water; the periods of opening are, however, of relatively short duration and pumping, if any, is weak and irregular.

CONCLUSIONS

Evidence presented in this paper shows that oysters are sensitive to the presence of free chlorine in sea water and some of them react to a concentration as low as 0.01 p. p. m. Both the adductor muscle and the pumping mechanism of the oyster may respond to this concentration. The initial treatment with concentrations varying from 0.01 to 0.02 p. p. m. may cause complete cessation of the current and closure of shells. Within the limits of the experiments, it was shown that an inhibition caused by the presence of free chlorine in water may continue for a varying period of time. It is frequently followed by attempts of the oyster to open its valves and to resume feeding. Flushing the oysters with fresh sea water restores their activity; their shells open, and pumping is resumed.

There exists considerable variation in the sensitivity of oysters to chlorine. Some of the observations suggest that low sensitivity to chemical and mechanical stimuli may be associated with the condition of sea water and the presence of pollutants. No uniform threshold of sensitivity could be established, therefore, for all the oysters.

Experimental evidence indicates, however, that initial concentrations varying from 0.01 to 0.05 p. p. m. will materially interfere with the normal functioning of some of the oysters and therefore would impede the process of their purification.

Repeated treatments develop tolerance, and pumping may be continued at concentrations much stronger than those which produced the strong initial effect. There is no evidence, however, that effective pumping may be maintained at concentrations exceeding 1.0 p. p. m., although the shells may remain open and ciliary motion continues.

After an exposure for 24 hours to air temperature of 5° C. and 30° C., oysters returned to water may not resume pumping for several days.

In full agreement with the finding of the British investigators, it is suggested that, for successful purification, oysters should be permitted to cleanse themselves by pumping water which has been sterilized by chlorination and which contains no residual free chlorine. The temperature during the process should be high enough to permit effective functioning of the gill epithelium. Chlorination of *O. virginica* should not be attempted at temperatures below 50° F. which greatly reduce the ciliary motion of the gill epithelium and render the pumping of water through the gills ineffective.

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UNITED STATES DEPARTMENT OF THE INTERIOR
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CARE AND DISEASES OF TROUT

Research Report No. 12

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CARE AND DISEASES OF TROUT

By H. S. DAVIS

Revised edition, 1946

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ABSTRACT

THIS IS the third and most extensive revision of Care and Diseases of Trout. Care of trout at the hatchery, including the care of ponds and raceways, is treated at some length. This is followed by a general discussion of trout foods and methods of feeding, special attention being paid to the use of dry products for supplementing fresh meat in the diet. Some consideration is given to the improvement of brood stock and its practical value.

A general discussion of parasites and diseases of trout, and their control, is followed by a detailed account of each disease, including the characteristic symptoms, etiology, pathology, and methods of control. The figures include drawings and photomicrographs of the more important organisms that cause trout diseases and their effects on the tissues.

CARE AND DISEASES OF TROUT[1]

By H. S. DAVIS, PH.D., *In charge, Aquicultural Investigations, Fish and Wildlife Service*

CONTENTS

Page
Introduction 1
Care of fingerling trout 2
Care of ponds and raceways 10
Trout foods 11
Feeding methods 18
Improvement of stock 19
Parasites and diseases 22
  General considerations 22
  General principles of disease control 23
  Sterilization of ponds and raceways 27
  External animal parasites 28
    Trematoda 28
      Gyrodactylus 28
      Discocotyle salmonis 30
    Parasitic copepods 31
    Mussel glochidia 33
    Protozoa 35
      Costia 35
      Chilodon 37
      Trichodina 39
      Ichthyophthirius 41
  Internal animal parasites 45
    Parasitic worms 45
    Protozoa 49
      Octomitus salmonis 49

Page
Internal animal parasites—Continued

      Schizamoeba salmonis 53
      Myxosporidia 54
      Coccidia in trout 55
  Bacterial diseases 55
    Furunculosis 55
    Ulcer disease 61
    Peduncle disease 63
    Fin rot 66
    Gill disease 68
    Western type of gill disease 73
    Cytophaga columnaris 74
  Miscellaneous diseases, including those of uncertain origin 77
    Fungus diseases 77
    Popeye 82
    Thyroid tumor or goiter 84
    Intestinal inflammation 85
    Fatty degeneration of the liver 85
    Acute catarrhal enteritis 87
    Anemia 88
    White-spot disease 89
    Blue-sac disease 89
    Soft-egg disease 91
Literature cited 92

INTRODUCTION

During recent years there has been a constantly increasing demand for larger trout for stocking purposes. At one time, most of the trout were planted as advanced fry or, at least, before they reached a length of 3 to 4 inches. Except in commercial hatcheries few fingerling trout were fed for more than 2 or 3 months. At present, most fingerlings are held for much longer periods and large numbers of trout from 6 to 12 inches or more in length are planted each year.

This change in stocking policy is due to the fact that in thickly populated sections, where the streams are fished intensively, even moderately good fishing can be maintained only by liberal plantings of large trout. Our streams can produce only a small part of the food required to support a trout population large enough to satisfy the demand in heavily fished waters. Either large trout must be supplied by hatcheries or fishing must be greatly curtailed.

It is a comparatively simple matter to produce advanced fry in large numbers with little loss, but if trout are to be held through the summer the trout culturist will be confronted with difficulties of various kinds, which must be met and overcome if the fish are to be kept healthy and growing rapidly during the summer.

There is every reason to believe that heavy losses are unnecessary and, to a considerable extent, can be prevented. There are well-authenticated instances of small lots of trout that have been carried through the first year with a total loss of less than 10 percent from the time the eggs were taken. No doubt this represents an exceptional condition that cannot be duplicated on a large scale, but, the fish culturist should try to approach this record.

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[1] Approved for publication June 1945.

There is always some loss among the eggs, especially before they are "eyed," which in many cases reaches 20 to 30 percent or more. From the time the eggs are eyed, however, until the young fish begin to feed, there is usually very little loss. The final absorption of the yolk sac, which compels the advanced fry to seek its food from other sources, marks a critical period in the life of the young trout, which is sometimes attended with heavy losses. From this time until late summer or fall the mortality is often heavy and it is during this period that there is the greatest opportunity to cut down losses through the adoption of better methods of caring for the fingerlings. Usually, little difficulty is experienced in carrying the trout through the ensuing winter if they are carefully graded according to size, so as to allow no opportunity for cannibalism.

CARE OF FINGERLING TROUT

Before discussing the conditions under which fingerling trout can be reared to best advantage, it is advisable to consider the natural habitat of young trout during the first few months of their lives. As is well known, trout normally spawn in the riffles of comparatively small, swiftly flowing streams. The young remain near the spawning grounds or work their way into even smaller streams during the first summer. In some instances, especially in northern localities, trout may spawn in ponds or lakes; but in such cases they usually seek gravel beds that are infiltrated with ground water from springs or seepage.

Small brooks in which trout normally spawn usually contain but few large pools; consequently, there is a perceptible current almost everywhere. Even in the larger streams the small fingerlings are almost invariably found in shallow riffles or small side channels where there is a decided current and the water is well aerated. This fact is emphasized as it is believed that the more nearly natural conditions can be approximated in rearing fingerling trout, the better will be the chances of success. This means that the fish should be held where there is an abundant supply of well-aerated water and a perceptible current.

Frequently, fingerling trout are held during their first summer in the troughs in which they were hatched. At many hatcheries, especially in the West, large troughs or tanks are provided to which fingerlings are transferred when the hatching troughs become too crowded. Unquestionably, these are superior to the standard hatchery troughs for rearing fingerlings and very good results are often obtained. Nevertheless, it is believed that there are several serious objections to rearing trout in either troughs or tanks, and that much better results would be obtained if the fish were moved outdoors early in the season. Standard hatchery troughs provide an ideal means of hatching eggs and holding the fry, but after the fish begin feeding, other factors must be taken into consideration. In the first place, the rapidly growing fish constantly require additional space if they are to be kept in vigorous condition. Consequently, if they are to be held for several months it will be necessary to have many times the number of troughs that were required to hold the eggs and fry. Troughs and tanks are expensive to build and to provide a sufficient number of these to hold the fingerlings throughout the summer will greatly increase the overhead. In fact, if the fish are given sufficient room, for best results, the cost of rearing them would be increased out of proportion to the results attained. Moreover, troughs and tanks are wasteful of water since they require a relatively large volume of flow for the number of fish carried. At hatcheries with a large water supply this may not be an objectionable feature, but where the supply is limited and it is necessary to utilize the water to best advantage, other methods of rearing fingerlings should be seriously considered. Owing to their limited capacity, troughs are usually overcrowded, with the result that the fish are stunted and not infrequently contract diseases which result in heavy mortality.

The number of fish that can be held in a trough without detriment to their growth or health will depend, of course, primarily on their size, and on the volume and temperature of the water. There is no general agreement among trout culturists as to the proper number of fingerlings of various sizes that can be safely carried in the standard hatchery trough. At some hatcheries, two or three times as many fish are habitually carried in the troughs as in others where conditions are very similar.

The results of an experiment to determine the effects of overcrowding of fingerlings in hatchery troughs are shown in figure 1. These experiments were carried on with rainbow fingerlings in 4 standard hatchery troughs. The dimensions of the space in which the fish were confined were 12.83 by 1.135 by 0.442 feet, equivalent to 6.436 cubic feet or 48.27 gallons of water. The troughs were supplied with slightly over 5 gallons of water per minute, thus, about 9 minutes were required for a complete change of water.

The experiment was started on March 1, 1933, with 500 rainbow fingerlings in the first trough, 1,000 in the second, 2,000 in the third, and 3,000 in the fourth. These trout were all from the same lot of fingerlings and the average individual weight of the fish in all four experimental lots was the same. Needless to say for all lots the diet and other conditions remained identical except for the number of fish present. It will be noted that up to April 26 when the fish reached an average weight of about 2.5 grams, there was very little difference in the average individual weight of the different lots. From that time on, however, the slower growth of the larger lots became more and more noticeable until July 19, when it became necessary to discontinue the lot con-

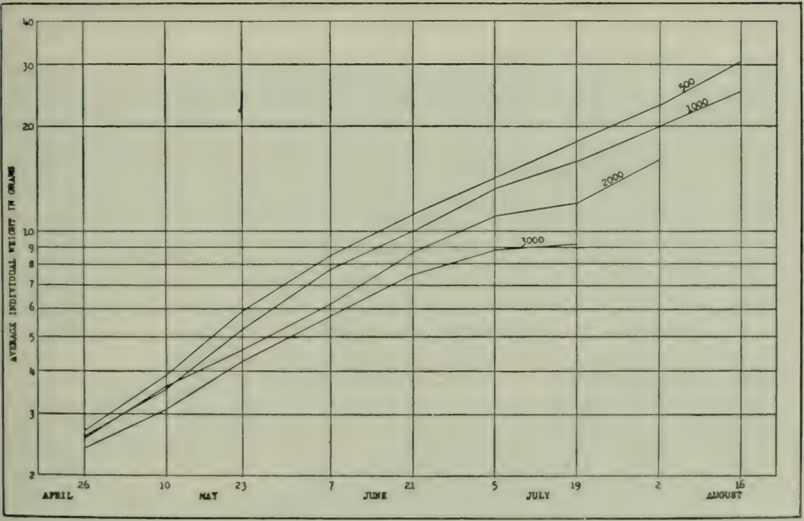

FIGURE 1.—Growth curves showing the effect of overcrowding on fingerling rainbow trout. The figures 500, 1,000, 2,000, and 3,000 indicate the number of trout in the troughs.

taining 3,000 fish owing to an outbreak of gill disease. At that time, both this trough and that containing 2,000 fish appeared overcrowded, and the dorsal fins of the fish were worn from constant milling in massed schools at the head or foot of the trough. The 2,000 lot was discontinued on August 2, but the 2 other lots were continued on an experimental basis until August 30. By that date, the fish in the smallest lot had far outgrown all the others. The rapid growth of the fish in this experiment was due to the comparatively high temperature of the water, which ranged from 54° to 56° F.

It is apparent from this experiment that when conditions are favorable for rapid growth, 1,000 trout is the maximum number that can be successfully held in a standard hatchery trough through the summer. At hatcheries where the growth is slower, because of lower temperatures, two or three times this number can be safely held in a single trough.

A series of experiments conducted by E. W. Surber at the Leetown (W. Va.) station to determine the amount of oxygen removed by trout from the water in troughs containing various numbers and sizes of fingerlings is also of interest in this connection. The troughs were similar to those used in the preceding experiment, with the same volume of water (48.27 gals.), and were supplied with water having a temperature of approximately 54°F. at the rate of 5.17 gallons per minute. The results of a few typical experiments will be sufficient for our purpose. It was found that 1,500 brook trout, averaging about 14 grams each, removed about 45 percent of the available oxygen from the trough. In a trough containing 17,680 rainbow trout fingerlings with an average weight of 0.26 grams, the amount of oxygen removed was only 24 percent of the total amount; while in another trough containing 16,735 fish, averaging 0.24 grams in weight, only 14.4 percent of oxygen was removed. In another experiment 9,975 rainbow fingerlings (average weight 0.59 grams) removed 34.89 percent of available oxygen, while in a later experiment 8,410 fish of the same size removed 27.22 percent.

In an experiment with black-spotted trout, 3,900 fingerlings, averaging 2.30 grams in weight, removed 18.02 percent of the total amount of oxygen. In another trough 41,600 Loch Leven trout fry 1-day old consumed only 3 percent of the available oxygen.

Feeding greatly increased the consumption of oxygen as shown in the case of a trough containing 1,500 brook trout with an average weight of 13.45 grams. On the morning of November 28, these fish were found to consume 3.07 parts of oxygen per million parts of water, or 29.63 percent. After the fish were fed 300 grams of food, 7.26 parts of oxygen per million of water or 70.08 percent of the total amount present was consumed in this trough. At 4:05 p.m., several hours after feeding, the consumption of oxygen in the same trough was only 4.72 parts per million, or 44.74 percent. At this time the fish were again given 300 grams of food and the oxygen consumption rose to 8.55 parts per million, or 81.04 percent of the total amount present. It is evident from these experiments that in overcrowded troughs there is a distinct possibility that during or shortly after feeding the oxygen content of the water may drop to dangerously low levels, even though at other times the supply may be more than sufficient for the needs of the fish.

It is believed that raceways (fig. 2) will provide a much more satisfactory means of holding trout than troughs. Obviously the raceway is only a development of the fundamental idea embodied in the hatchery trough, but considering the number of fish that it will support, it is much cheaper to build and operate. It has the further advantage, if properly constructed, of providing an environment closely simulating that of fingerlings in nature. This is especially true if the raceway has a sand or gravel bottom, as it should have wherever practicable.

Raceways may vary widely in size, depending on local conditions, but in any event they should be much longer than wide, and supplied with sufficient water to insure good circulation. Unless an exceptionally large flow of water is available, raceways intended primarily for fingerling trout, should not be over 3 to 5 feet wide, with a maximum length of 50 to 75 feet. Where the soil is light and porous, wooden or concrete sides for the raceways are usually necessary, but, unless essential in order to retain the water, a dirt bottom is to be preferred, although it is usually best to cover this with a layer of sand or gravel. Only a slight slope of the bottom is necessary, and ordinarily the water in the lowest part should not be over 20 or 25 inches deep. For small fingerlings the depth should be considerably less. The proper depth of water in the raceway is dependent to a large extent on the volume of flow. Where a large flow is available, the depth of the water may be greater than with a small flow. The important consideration is to have good circulation with an appreciable current in all parts of the raceway. It is also well to remember that the higher the temperature, the greater should be the volume of flow with the same depth of water and poundage of fish.

Many trout culturists use much deeper water than is advocated in the previous paragraph, and where there is a sufficient volume flowing through the raceway, this may prove satisfactory; but it is believed that with a relatively small supply more fish can be held safely in shallow than in deep raceways. This is due to the fact that it requires a greater flow to produce a current in a deep than in a shallow raceway. It is true that in a shallow raceway it may not be possible to hold quite as many fish per unit area of water surface, but, on the other hand, it requires less water to provide a satisfactory circulation.

After the fingerlings reach a length of 4 or 5 inches, they may be held safely in small pools in which there is a less rapid circulation than raceways. Fingerlings smaller than this are often held in pools successfully if given plenty of room, but our experience indicates that, in most cases, it will prove more economical to hold such fish in raceways and, if thought advisable, remove

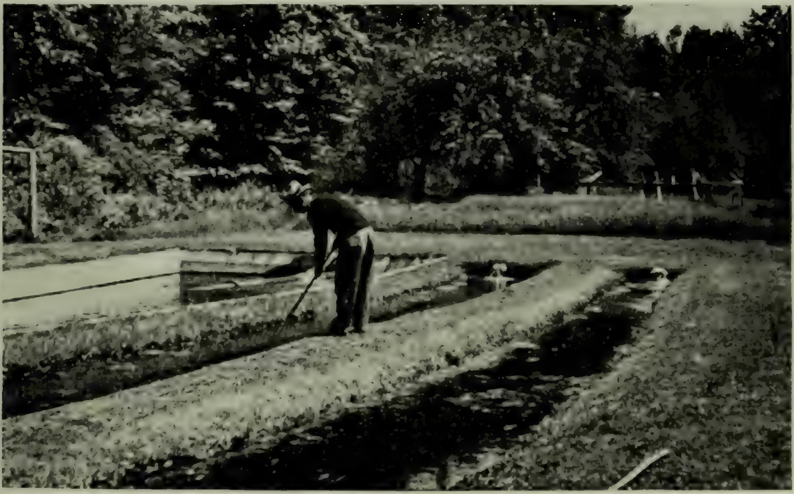

FIGURE 2.—Raceways for fingerling trout at the Pittsford (Vt.) Experimental Hatchery.

them to pools later in the season. A very good arrangement is to provide pools to which the surplus fish can be transferred when the raceways become overcrowded.

The type of pools or raceways to be employed will, of course, depend more or less on local conditions. Where there is danger of the water becoming overheated, this fact must be taken into consideration and the pools so constructed that there will be no possibility of such an occurrence. In rapid, well-aerated streams brook trout can withstand temperatures as high as 80°F. for a short time without serious injury. Under similar conditions rainbow and brown trout can survive somewhat higher temperatures. However, such high temperatures may produce disastrous results in hatchery waters. Where the fish are crowded together in small pools there is likely to be a deficiency in dissolved oxygen when the water becomes warm, and under such circumstances high temperatures are much more injurious. Furthermore, hatchery fish are usually not so strong and vigorous as those living in a natural environment and consequently succumb more quickly to adverse conditions.

Ordinarily, a temperature higher than 65°F. should not be allowed in rearing pools, and, where practicable, the water should be kept below that temperature. Trout appear to grow most rapidly at 55° to 60°F., and at higher temperatures their vitality is lowered and they are more liable to contract some disease.

Overheating of the water can often be prevented by partially shading the pools and raceways. In fact, this is advisable even where there is no danger of overheating, as it has been found that small fingerlings usually do better when given an opportunity to escape from the intense light of the midday sun.

In addition to providing more natural conditions for young trout, raceways have a distinct advantage over troughs in that they require much less attention. Troughs must be cleaned at least once a day, but even heavily stocked raceways usually need not be cleaned oftener than once or twice a week. Instances are on record where the fish apparently suffered no ill effects even though the raceways were left for several weeks without any attention other than to clean the screens so that the water could circulate freely. In an experiment conducted at the Service's Pittsford (Vt.) experimental hatchery, fingerling brook trout were allowed to remain in a raceway from April to October without cleaning, and there was virtually no mortality during this period. Moreover, the fish were more vigorous, better colored, and made more rapid growth than those held in troughs. There were about 6,000 fingerlings in the raceway, which was 4 feet wide, 37 feet long, with a depth of 10 to 12 inches. The water supply fluctuated from 20 to 30 gallons per minute. This experiment is mentioned not with the intention of advocating that raceways should not be cleaned frequently, but simply to show that extreme cleanliness is unnecessary under such conditions.

As a matter of fact, raceways, like polluted streams, have a remarkable capacity for self-purification, which is accomplished in much the same way. The excrement accumulates on the bottom and supports a luxuriant growth of small organisms, including bacteria, algae, protozoa, and insect larvae, which quickly causes its distintegration, so that the organic compounds are reduced to nontoxic, inorganic substances. The decaying excrement contains large numbers of chironomid larvae, that trout eat readily, and these, together with algae, form a not inconsiderable portion of the food of the young fingerlings. It is not improbable that this "natural" food is largely responsible for the greater vigor of fish reared under such conditions.

During recent years the circular pool has been growing rapidly in favor and, for fingerlings at least, promises largely to supplant the orthodox type of pool and the raceway described previously. The superiority of the circular pool for yearling and larger trout is not so evident, and it is probable that for fish of this size the older type of pool will still retain its popularity.

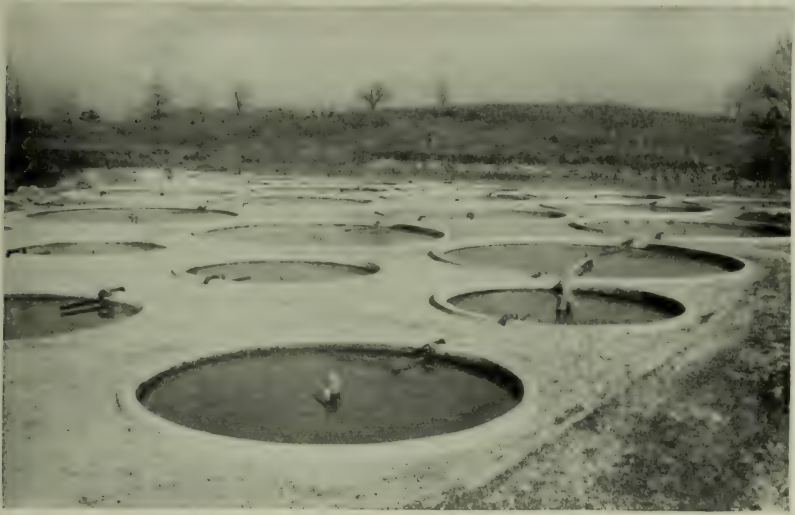

FIGURE 3.—Circular rearing pools at the Leetown (W. Va.) Experimental Hatchery.

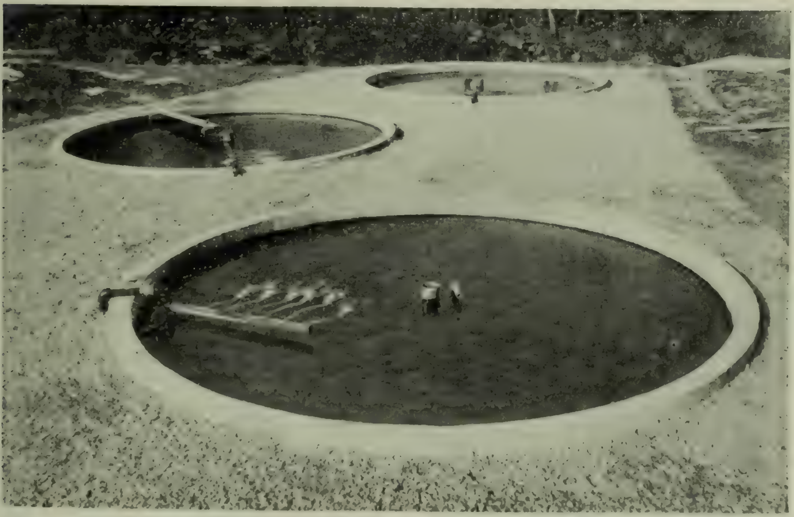

FIGURE 4.—Near view of circular rearing pools at the Leetown Experimental Hatchery.

The construction of a circular pool (figs. 3 and 4) is very simple. It consists essentially of a basin-shaped excavation with the bottom sloping gradually toward the center. Various types of circular pools are in use, but experience has indicated that a relatively shallow pool, 15 to 25 feet in diameter, is most satisfactory. In these pools the water is not over 18 or 20 inches deep at the center and 8 or 10 inches deep at the margin. The bottom should have a gradual slope toward the outlet at the center, and both the sides and bottom should be of concrete, since it is not possible with a dirt bottom to maintain such a slope for any length of time. The water may enter through the open end of the supply pipe, but a better circulation is obtained by boring several small openings on the side of the pipe that projects over the pool as shown in figure 4. With this type of inlet it is surprising how little water is required to maintain a good circulation. The water, preferably under considerable pressure, enters tangentially at one side of the pool and flows out through an outlet pipe at the center. It travels in a circular path and makes a number of circuits before leaving through the overflow pipe. Consequently, there is a nearly uniform circulation of water throughout the pool, and the fish are evenly distributed instead of massed near the outlet as so frequently occurs in raceways and pools of the older type. The fish have a better chance to extract oxygen from the water, and consequently a circular pool will carry several times the number of fish that can be held in a long pool of the same volume of flow. The fish also have more opportunity for exercise, and they can frequently be seen swimming around and around the pool in orderly succession. Another distinct advantage of this type of pool is the fact that there is nothing against which trout can jump and injure themselves, as is frequently the case in raceways unless special precautions are taken.

To one who has had experience only with raceways, the number of fish that can be carried in a circular pool is almost unbelievable. At the Leetown station, 20,000 rainbow fingerlings, with an average weight of 2.3 grams, were placed on June 11 in a pool 15 feet in diameter. The pool was 18 inches deep at the center and received 12.4 gallons of water per minute. These fish remained in the pool with practically no mortality until September 6, at which time the average individual weight was 8.8 grams. The total weight of the fish in the pool at this time was approximately 387 pounds. A second pool of the same size was stocked on June 2 with 15,000 rainbow fingerlings, averaging 1.9 grams in weight. These fish remained in the pool with practically no losses until September 2, when the average individual weight was 11.5 grams. It is of interest to note that the total weight of the fish in this pool was practically the same as in the pool containing the larger number of fish. Although both pools were fully exposed to direct sunlight, the highest temperature recorded was 64°F. at 4:25 p.m., July 28, when the air temperature was 100°F. The temperature of the water as it entered the pool was about 56°F.

One of the great advantages of the circular pool is that the excrement and other wastes collect at the base of the outlet pipe in the center where they can be easily removed by a siphon. A self-cleaning device has been developed at the Leetown station, which automatically removes all waste material and greatly simplifies the operation of this type of pool. This device consists of a large sleeve which is attached to the outlet pipe and extends for a short distance above the surface of the water. At the bottom there is a narrow opening between the sleeve and a sloping flange which rests on the bottom of the pool. The width of this opening can be easily adjusted according to the size of the fish in the pool. Excrement and other waste materials are drawn into the opening by water flowing through the outlet pipe, thus keeping the pool clean.

There is considerable difference of opinion among trout culturists with respect to the age at which the fingerlings should be removed from the troughs. Probably under ordinary circumstances the sooner the fish are removed to raceways after they begin to feed the better.

Apparently, the most common practice is to hold the fish in troughs for several months and in early summer transfer them to raceways or pools. This practice appears to be predicated largely on the fact that while in the troughs the fish are under more immediate control and can be watched more carefully than when in raceways. While this is undoubtedly true, it is questionable that this outweighs the obvious advantages that fish in raceways enjoy.

It is held by those who believe in keeping the fish in troughs for the first few months that when they are transferred to raceways early in the season, there is always considerable loss which cannot be accounted for by the number of dead fish recovered. Consequently, when the fish are finally removed, their number is always much less than is indicated by the mortality record. This is undoubtedly true, but if the raceways are properly constructed, and the fish graded frequently (as they should be) and protected from enemies, it is believed that this discrepancy will be not much greater than if the fish were held in troughs over the same period. In virtually all cases the so-called "uncounted mortality," which has been emphasized so much, is due, either to improper construction of the raceways, so that many of the fish are able to escape; to the attacks of enemies, such as fish-eating birds; or to cannibalism. The first two of these factors can be virtually eliminated by proper construction at comparatively small expense. It should be remembered that young fingerlings can wriggle their way through an almost inconceivably small opening, and all head and foot screens should be constructed accordingly. Protection from birds and other enemies can be assured by covering the raceways with wire netting.

In many cases it is probable that most of the "uncounted losses" are due to cannibalism, which is doubtless more rampant in raceways or pools than in troughs. It may seem paradoxical, but experiments have shown that cannibalism is greatest among well-fed, rapidly growing fish, not among those that are weak and underfed. Fortunately, cannibalism can be prevented by grading the fish at frequent intervals, so that only those of approximately equal size are held in the same compartment.

It seems to be best in most cases not to transfer the fish to raceways until after they have learned to feed, although experimental work has shown that they can be taught to take food in raceways nearly as readily as in troughs. As previously pointed out, when the fingerlings reach a length of 3 or 4 inches they may be removed to pools which should be so designed as to simulate natural conditions as closely as possible. Pools with dirt bottoms are much superior to those with bottoms of concrete, and unless the soil is of such a nature as to require wood or concrete sides, these should be dispensed with.

The size of rearing pools is dependent largely on local conditions, but generally speaking, comparatively small pools are preferable. Also they should be quite shallow, with a maximum depth of 2 or 3 feet, unless it is necessary to use a greater depth to prevent the water becoming too warm during hot weather. Needless to say, it is essential that the ponds have a copious supply of pure, cold water, and that they should be so constructed as to insure a good circulation throughout. The deepest part of the pond should be at the outlet, toward which the bottom should slope gradually from all sides, so that the pond can be easily drained and the fish removed with little trouble.

When the water supply is limited, the ponds may be arranged in series, one below another, which allows the same water to be used several times. Of course, this is objectionable from the sanitary standpoint, since any disease in the upper ponds would be transmitted immediately to fish in those below. For this reason, it is not advisable to resort to such an arrangement unless it is necessary. However, with the exception of furunculosis, yearlings and older fish are seldom seriously affected by infectious diseases, and therefore the danger is not so great as would at first appear. It is well to bear in mind that, whenever ponds are arranged in series, fingerlings should never be placed in those receiving the drainage from ponds containing older fish. Yearlings and brood fish often harbor parasites, which, while not seriously affecting them, may produce disastrous results when transmitted to fingerlings.

CARE OF PONDS AND RACEWAYS

It is scarcely necessary to point out that raceways and rearing ponds should always be kept in good sanitary condition. No food should be allowed to collect on the bottom, and the excrement should be removed frequently enough to prevent the water from becoming polluted. It is difficult to give detailed advice, since the care necessary to keep pools and raceways in sanitary condition will vary widely with conditions.

As pointed out, ponds and raceways do not require such close attention as troughs, because a certain amount of filth is automatically taken care of without detriment to the fish. The efficiency of self-purification naturally will vary with the number of fish contained in the pools. If the fish are relatively few, it may be necessary to clean the ponds at only infrequent intervals. Instances are known of fish kept in ponds with dirt bottoms which were cleaned only at intervals of several months. Although there was an average of one 6- to 8-inch fish per square foot of surface area, there was no evidence that the fish were affected unfavorably. Under ordinary conditions, however, the accumulated filth should be removed more frequently to prevent any injurious effects from the decaying excrement. When cleaning the pools, every precaution should be taken to avoid injury to the fish. The practice of going over the bottom with a broom or some similar implement and thus stirring up the material that has accumulated is highly objectionable, as it always results in considerable injury to the fish. Moreover, this practice necessarily removes most of the algae, which is in itself inadvisable. Unless unduly abundant, algae have a beneficial effect, and their growth should be encouraged. There are no more efficient agents in keeping the ponds in a sanitary condition than the algae and associated organisms. Not only do they aid in aerating the water and keeping it free from objectionable substances, but trout feed on them to a considerable extent, and they, no doubt, perform much the same function in the trout's metabolism as do vegetables in the human diet.

A much better and more logical way to remove the excrement and other filth on the bottom of the pools and raceways is to employ some suction device that will avoid stirring up the material or injuring the fish. If this is not feasible, the lowest part of the pool should be connected with a drain, through which most of the filth can be drawn off with little trouble.

In this connection a word of caution should be addressed to those who are about to clean pools in which excrement and, more especially, surplus food has been allowed to accumulate for a considerable time. Under such circumstances a layer of decomposing material may form on the bottom, which does not appreciably affect the overlying water as long as it is undisturbed. This layer has a high oxygen demand, contains noxious gases and other toxic substances, which are liberated as soon as the material is moved, and if the fish remain in the pool, there is danger that they may be killed. In such cases the fish should be removed from the pond before any attempt is made to disturb the filth on the bottom. Even after the pond has been cleaned, it is best to allow the water to flow through it for a short time before the fish are returned. When practicable, it is best to drain all ponds occasionally and allow them to remain dry for several days. If this is done once or twice a year, the ponds will be in better condition than if kept filled continuously.

TROUT FOODS

There is probably no question on which fish culturists differ more widely than in regard to what constitutes the most satisfactory food for trout. During recent years this problem has received much attention, and diets greatly superior to those formerly used have been developed, but, nevertheless, there is still no general agreement as to the best and most economical diets to use under all circumstances.

It is safe to say that, with the exception of the water supply, no single factor is of more importance in determining the success or failure of a hatchery than the daily diet of the fish. If strong, healthy fish are to be developed, they must be provided with suitable food, and it is no small problem to determine what food or what combination of foods may be relied on to give the best results under average conditions.

In any consideration of trout foods it should be remembered that rapidity of growth is not the only factor of importance. Too often in the past this has been virtually the only criterion used in evaluating a trout food. Rapid growth is very desirable, but it should not be procured at the expense of the health and vigor of the fish. The Federal and State hatcheries are raising fish to be liberated in natural waters where they will be obliged to fend for themselves. It is very doubtful that the fat, lazy, pot-bellied fish so often seen in hatcheries are as well able to care for themselves when thrown upon their own resources, as are fish which have not been pampered or subjected to an abnormal forcing process. For stocking purposes there are needed hardy, vigorous fish that can adapt themselves quickly to their new environment.

It is important to bear in mind that the trout culturist does not have an unlimited number of foods at his disposal, from which to choose. He is, in fact, bound hand and foot, since any food to be considered seriously must be obtained at a reasonable cost, and there must be an adequate supply available at all times.

Available trout foods may conveniently be divided into three groups. In the first group are fresh meats such as horse meat, and the liver, lungs, and spleen of cattle, sheep, and hogs. The second group embraces various dried animal meals; while the third group includes plant products, such as wheat middlings, low grades of flour, shorts, cottonseed meal, soybean meal, and peanut meal. In a Federal fisheries survey conducted in 1935, it was found that sheep plucks were used to a greater extent than any other food. Other products that were fed in large quantities were beef, sheep, and pig liver, horse meat, cereal products, and fish. Since that time, extensive changes have been made in trout diets, with resultant greater emphasis on dry products.

As in the case of higher animals, fish require a certain amount of proteins, carbohydrates, and fats in their diet as well as various inorganic substances, such as lime and salt. These mineral constituents, of which there are a large number, are just as necessary as the fats and proteins. In addition, fish, like higher animals, require vitamins, even though these are present only in very minute quantities.

Recent experiments have greatly increased our knowledge of the vitamin requirements of trout. A deficiency of vitamin B_1 where fresh or frozen fish are fed to trout has been shown to result in serious mortality by several workers. (Wolf, 1942; Tunison *et al*, 1942; Woodbury, 1942.) Tunison and his coworkers (1943) found that 3 vitamins of the B-complex were involved in the production of anemia in trout on a synthetic diet. On the other hand Simmons and Norris (1941) reported that lack of xanthopterin was responsible for the anemia which developed when no raw meat was included in the diet. Wolf (1944) and Tunison *et al* (1944) found that pantothenic acid deficiency was responsible for a form of gill disease. That still other vitamins are essential to trout is indicated by the benefits derived from the addition of yeast and cod liver oil to the diet which are far greater than can be accounted for on the basis of their calorific value. It is evident that despite our increased knowledge of the value of vitamins in the nutritional economy of trout, much work remains to be done before it will be possible to complete the story of their vitamin requirements.

It has been common knowledge among fish culturists for years that trout could not be reared successfully without the inclusion of raw meat in the diet. This fact, which has been demonstrated time and again, led McCay and Dilley (1927) to postulate a hypothetical factor H which is present in virtually all raw meats, but is found to only a very limited extent in cooked or dried products. All efforts by McCay and his coworkers to isolate factor H have been unsuccessful, which is not surprising, since it now appears that in all probability there is no such substance. Recent experiments indicate that the beneficial effects attributed to factor H result from several vitamins, all of which must be present at the same time and that one of the first indications of a deficiency of these vitamins is the appearance of an anemic condition. All workers, however, are not agreed as to the vitamins that together constitute factor H. Simmons and Norris (1941) believe xanthopterin to be the principle constituent, but Bridge (1943) concludes that factor H contains both a growth factor and an anti-anemic factor and that these are distinct and separate. Tunison *et al* (1943) believe that at least 3 vitamins —pantothenic acid, riboflavin, and pyridoxine—are concerned in the factor H complex.

In any consideration of trout foods, it is well to bear in mind that there is evidence that the nutritional requirements of the various species of trout may differ in some respects. Rainbow trout, for instance, appear to be more susceptible to dietary deficiencies than are brook trout. This opinion, based on hatchery experience, receives additional support from the fact that all food studies of wild fish have shown that a considerable percentage of the food of rainbow trout consists of algae; while in the case of brook trout the occurrence of these plants in the stomach contents appears to be entirely accidental. Nevertheless, it is undoubtedly true that diets which have been found to give excellent results with one species of trout will in all probability give good results with other species.

Another essential in any trout food is its palatability. Obviously, if a food is to produce rapid growth it must be taken readily by the fish; for, while hunger may drive them to eat unpalatable foods in small quantities, such a diet will never produce vigorous, rapidly growing fish. Experience has shown that this is the reason for the failure of some apparently good foods to yield satisfactory results. They may contain the proper proportions of proteins, carbohydrates, and fats, as well as sufficient vitamins, but if they are not palatable, the fish will suffer from partial starvation even though there is always a supply of the food available.

It has been the universal experience of fish culturists that trout can be reared successfully on a straight meat diet, although there is much difference of opinion as to which meat gives the best results. Everything considered, probably no meat has proved more satisfactory for young fingerlings than beef liver, and undoubtedly this would be used much more extensively were it not for the fact that its cost has increased greatly in the past few years. However, experiments with both brook and rainbow fingerlings have shown that, in general, a mixed diet is preferable to one composed of a single meat product, and that better results are obtained when beef liver is mixed with beef heart than when it is used alone.

There can be little doubt that the results attained with various meat products are dependent on both their chemical and physical structure, and the latter should not by any means be ignored. This probably accounts for the fact that beef heart has been found superior to beef liver as a food for advanced fry and very young fingerlings. The heart can be ground into very fine particles, which are easily swallowed by the young fish, while the liver forms a thick, mush-like material not so readily separable into discrete particles. Furthermore, a considerable percentage of the ground liver is readily soluble in water, and there is, therefore, from this source an appreciable loss in food value.

As the fish increase in size they are naturally able to ingest larger particles, and to devour the food more quickly. Consequently, there is less loss from solution, and liver will thus produce a faster growth than heart, although there is usually a higher mortality. By combining heart and liver in a mixed diet the growth is virtually as great as with liver alone, while the mortality is comparable to that of fish kept on a straight heart diet.

In our experiments pig liver and sheep liver, when fed straight to young fingerlings, have not given good results. However, sheep liver produced a better growth with rainbow than with brook trout, although even with the former species the results were not so satisfactory as with beef liver and beef heart. Both pig and sheep liver give better results when mixed with other products than when fed alone.

Beef and pig melts, or spleen, are among the cheapest foods available to fish culturists, and for that reason are used extensively at many trout hatcheries. In our experiments these products have always produced relatively slow growth as compared with liver and other superior diets. The mortality, however, was low, and owing to their lower cost, it may be advisable where rapid growth is not essential to include these products in the diet. Later experiments indicate that beef melts are definitely superior to pig melts.

Melts should always be supplemented by some other meat or by dry meal, since Hess (1937) has shown that when fed alone, a considerable percentage of the fish after a time develop cataract. The disease appears as a distinct opaqueness in the lenses of both eyes. Hess believed the development of cataract was due to a vitamin deficiency, and McCay and Phillips (1940) have shown that it is caused probably by a deficiency of vitamin A.

While only a few meats have been successfully fed to small fingerlings, a considerably greater variety is available for fish 3 to 4 inches long and larger. Fish of this size do much better on pig and sheep liver than do very young fingerlings, and beef lungs and sheep plucks may also be fed. Here again, however, a mixture of two or more kinds of meat usually gives better results than one meat alone.

Fresh fish of the coarser and cheaper grades have been utilized to a considerable extent for trout food, but in most cases the results have not been entirely satisfactory. It usually requires about twice as much fish as meat to produce an equal growth, and the trout are often not as healthy as those on a meat diet. Furthermore, it is much more difficult to keep fish in fresh condition than it is to keep meat, and the eating of decayed fish is liable to kill trout. It has been shown by Gutsell (1940) that frozen fish, when fed to trout continuously for several months in a proportion greater than 20 percent, may cause serious losses. After a time, the fish become much darker than normal, lose their balance and swim on one side. This condition is frequently followed by blindness, and eventually the fish die. Later Wolf (1942) showed that the trouble is caused by a vitamin B_1 deficiency due to the presence of an enzyme in fish flesh that destroys the vitamin in substances mixed with it.

According to Deutsch and Hasler (1943) the following species of fish contain the enzyme that destroys vitamin B_1: whitefish, smelt, carp, goldfish, creek chub, fathead minnow, buckeye shiner, sucker, channel catfish, bullhead, mudminnow, white bass, sauger, burbot, and salt-water herring. Species of fish which do not contain the enzyme include garpike, dogfish, Lake Superior herring, lake trout, rainbow trout, brown trout, pickerel, wall-eyed pike, perch, bluegill sunfish, rock bass, cod, haddock, mackerel, whiting, sole, redfish, and dabs. In order to avoid any possibility of B_1 deficiency fish should be fed separately and not mixed with other constituents of the diet.

Owing to the high cost of fresh meats, it is not in most instances economical to keep trout on a diet composed of only fresh meat after they reach a length of about 2 inches. Up to that time, the cost of food is a relatively unimportant factor, but as the fish increase in size, one of the greatest problems of the trout culturist is to find a diet that will produce large, healthy fish at the lowest possible cost. This has led to the extensive use of dry products, which are not only more economical than meats, but if fed properly, will produce fully as good, if not better, fish than can be grown on a straight meat diet.

The dried products that have given the best results as substitutes for part of a fresh-meat diet are those of animal origin. A variety of such products are now available and ordinarily are obtainable in any quantity desired. Among the animal meals that have proved most satisfactory are salmon meal, white fish meal, sardine meal, meat meal, dried skimmed milk, and dried buttermilk. The fish meals should be vacuum dried and the dried milk manufactured by the spray process.

When dry meals are included in the diet of small fingerlings, it is best to start with a limited amount say from 10 to 20 percent, and gradually increase the percentage as the fish grow and become accustomed to the food. Experiments have shown that after the fish reach a length of 4 or 5 inches, as much as 70 percent of the better meals may be included in the diet without injurious effects. However, when dry meals are fed at a level higher than 50 percent, the food is utilized less efficiently than at lower levels. Nevertheless, owing to the lower cost of dry feeds, it may be economical to use them at higher levels even though the waste may be somewhat greater.

In general, it is advisable to use a mixture of dry feeds rather than one alone. A mixture which produced good results in experiments is composed of equal parts of meat meal, salmon-egg meal, white fish meal, and dried buttermilk (Gutsell, 1940). In later experiments, a mixture composed of 2 parts of white fish meal, 1 part meat meal, and 1 part dried buttermilk gave somewhat better results at a lower cost. The addition of 3 percent of cod liver oil to various meals and meal mixtures used by Gutsell and 3 percent kelp meal resulted in a considerable increase in fingerling growth and a more economical utilization of the food.

In preparing mixtures of fresh meat and meals it has been found best in most cases to mix the meat directly with the meal without preliminary moistening. After roughly mixing the meat and meals together in the proper proportions, it is best to complete the operation by forcing the mixture through a grinder or a mechanical mixer. This results in a more complete mix than can be produced by hand, and there is consequently less loss in feeding. Liver, on account of its consistency, is more satisfactory for use with dry meals than heart or plucks. This is especially true of pig liver, which when ground is more sticky than either beef or sheep liver. For small fingerlings, however, beef liver will probably be found better, despite its greater cost. For large fingerlings and older fish, either sheep or pig liver appears to be satisfactory. In some sections melts are popular as the meat constituent of the diet. They are not only cheaper than most other meats, but when mixed with 2 percent salt, have a very sticky consistency and thus make an excellent binder for dry meals. To obtain the best consistency, the salt should be added to the melts while they are partially frozen.

Some trout culturists feed dry foods alone instead of in mixture with fresh meat. In such cases it is, of course, necessary to give the fish a meal of fresh meat occasionally to counteract the ill effects of an all-dry diet. While this method of feeding permits the use of a large percentage of dry foods, there is always much more waste than when a mixture is used, and for that reason, it is not recommended.

In comparing the cost of fresh meats and dry animal meals, it may appear at first glance that the latter are more expensive, but it must be remembered that fresh meats contain 70 percent or more of water, while dry meals contain only about 10 percent. This means that the price of all fresh meats should be multiplied by three in order to obtain a fair cost comparison with that of dry products. Table 1 shows the results obtained at the Leetown station with some of the better experimental diets. The list is far from complete, but will give some idea of the comparative value of various food mixtures. In order to avoid any misunderstanding, it may be well to point out that the weight of food required to produce a pound of fish is the actual weight of the mixture as fed. For example, 5 pounds of a mixture of 60 percent liver and 40 percent white fish meal would contain 3 pounds of ground liver and 2 pounds of dry fish meal.

The vegetable products that have been used in trout diets include cereals and the so-called protein concentrates. Wheat middlings and low grades of flour are probably fed to a greater extent than other cereal products, although bran, shorts, and other meals are also utilized. The protein concentrates are cottonseed meal, soybean meal, and peanut meal, which differ from cereals chiefly in their high protein content.

There is much difference of opinion regarding the relative value of plant and animal meals in the diet of trout. Experiments have been unfavorable to the use of vegetable products, since fish maintained on diets containing considerable amounts of cereals or protein concentrates have consistently made a much slower growth than those on diets containing the same amounts of

TABLE 1.—*Comparative growth and mortality of fingerling trout on experimental diets, Leetown (W. Va.) station*

MAY 6 TO SEPTEMBER 23, 1932

Species	Diet (percentage each constituent)	Final average weight	Increase in average weight	Feed to produce 1 lb. of growth	Mortality
		Grams	*Percent*	*Pounds*	*Percent*
Rainbow Trout	Beef liver 100	13.9	900	4.2	6.4
Do	Beef liver 70, salmon-egg meal 30	17.4	1,239	3.29	1.6
Do	Beef liver 60 meat meal 40	16.4	1,071	2.88	1.7
Do	Beef liver 60, dried buttermilk 40	13.7	878	2.14	2.3
Do	Beef liver 70, cottonseed meal 30	9	543	5.18	9.8
Brook Trout	Beef liver 70, salmon-egg meal 30	23.4	2,027	2.06	4.2
MAY 23 TO OCTOBER 11, 1939					
Brook Trout	Sheep liver 60, white fish meal 40	48	1,043	2.78	.2
Do	Sheep liver, 58.2, white fish meal 38.8, cod liver oil 3	53.8	1,279	2.60	.8
Do	Sheep liver 58.2, white fish meal 38.8, kelp meal 3	51.6	1,223	2.65	.7
Do	Sheep liver 58, white fish meal 36, kelp meal 3, cod liver oil 3	54.8	1,342	2.61	.5
Rainbow Trout	Sheep liver 60, white fish meal 40	41.7	1,091	2.97	0
Do	Sheep liver 58, white fish meal 36, kelp meal 3, cod liver oil 3	49.2	1,267	2.77	0
Do	Sheep liver 50, white fish meal 50	43	1,032	2.91	.8
Do	Sheep liver 48.5, white fish meal 48.5, cod liver oil 3	45.1	1,153	2.74	0
JUNE 10 TO OCTOBER 29, 1940					
Rainbow Trout	Sheep liver 60, L–40–A dry mixture[1] 40	54.6	1,170	2.80	.3
Do	Sheep liver 58.2, L–40–A dry mixture 38.8. cod liver oil 3	61.8	1,337	2.63	0
Do	Sheep liver 58.2, L–40–A dry mixture 38.8, kelp meal 3	50.1	1,065	2.88	.7
Do	Sheep liver 60, meat meal 40	48.5	1,055	2.75	3.7
Do	Sheep liver 58, L–40–A dry mixture 36, kelp meal 3, cod liver oil 3	60.8	1,348	2.59	0
MAY 4 TO OCTOBER 15, 1941					
Rainbow Trout	Sheep liver 50, L–40–B[2] dry mixture 48, salt 2	44.7	964	3.00	4.9
Do	Sheep liver 25, pork melts 25, L–40–B dry mixture 48, salt 2	42.3	907	3.03	2.1
Do	Pork melts 50, L–40–B dry mixture 48, salt 2	37.9	824	3.28	6.7
Do	Sheep liver 50, No. 12 Cortland dry mixture[3] 48, salt 2	34.4	739	3.26	.3
Do	Sheep liver 25, pork melts 25, No. 12 Cortland dry mixture 48, salt 2	34.4	739	3.25	0
Do	Pork melts 50, No. 12 Cortland dry mixture 48, salt 2	29.9	612	3.49	1.8
MAY 20 TO OCTOBER 6, 1942					
Rainbow Trout	Beef melts 50, cottonseed meal 48, salt 2	16.8	380	4.75	4.9
Do	Beef melts 50, soybean meal 48, salt 2	26.4	654	3.81	30.3
Do	Beef melts 50, peanut meal 48, salt 2	28	700	3.52	16.5
Do	Beef melts 50, cottonseed meal 16, soybean meal 16, white fish meal 16, salt 2	33.8	866	3.33	8.8
Do	Beef melts 50, cottonseed meal 16, peanut meal 16, white fish meal 16, salt 2	30.4	744	3.35	4.2
Do	Beef melts 50, soybean meal 16, peanut meal 16, white fish meal 16, salt 2	38.3	994	3.06	18.6

[1] The L–40–A dry mixture was composed of 2 parts white fish meal, 1 part Valentine's meat meal and 1 part dried buttermilk.

[2] The L–40–B dry mixture was like the L–40–A dry mixture except that instead of Valentine's "meat meal", a beef scrap meal of high protein content (60% or higher), from a large packing house, was used.

[3] No. 12 Cortland dry mixture is composed of 1 part white fish meal, 1 part cottonseed meal, 1 part flour middlings, and 1 part of roller dried skim milk.

animal meals. Of course plant meals are much cheaper than animal meals and that appears to be the principal reason for their extensive use.

Cereals, especially, have a high starch content, and it still remains to be proved that diets rich in starch are satisfactory for trout. Recent experiments by Phillips (1940; Phillips and Tunison, 1940) are inconclusive. It was found

TABLE 2.—*Comparative growth and mortality of fingerling trout, with cost of feed to produce 1 pound of trout, Leetown (W. Va.) hatchery*

JUNE 7 TO SEPTEMBER 29, 1944

Species	Diet (percentage each constituent)	Initial average weight	Final average weight	Increase in average weight	Feed to produce 1 lb. of growth	Mortality	Cost of feed to produce 1 lb. of growth
		Grams	*Grams*	*Percent*	*Pounds*	*Percent*	*Dollars*
Rainbow Trout	Beef melts[1] 50, salt 1, white fish meal 49	10.0	43.1	331	2.97	5	$ 103
Do	Beef melts 50, salt 1, white fish meal 39.2, dried yeast 9.8	10.2	49.6	386	2.66	1	.136
Do	Beef melts 50, salt 1, white fish meal 36.75, dried skim milk[2] 12.25	9.9	44.1	345	2.87	5	.124
Do	Beef melts 50, salt 1, white fish meal 24.5, dried skim milk 12.25, beef scrap meal (60 percent protein-12.25	10.2	42.0	312	3.10	0	.138
Do	Beef melts 50, salt 1, white fish meal 24.5, dried skim milk 12.25, peanut meal 12.25	10.2	41.0	318	3.02	.5	.129
Do	Beef melts 50, salt 1, white fish meal 24.5, dried skim milk 12.25, cottonseed meal 12.25	10.0	39.3	293	3.18	.5	.136
Do	Beef melts 50, salt 1, white fish meal 24.5, peanut meal 12.25, bran 12.25	10.0	40.0	300	3.16	.5	.104
Do	Beef melts 50, salt 1, white fish meal 24.5, cottonseed meal 12.25, flour middlings 12.25	9.6	41.0	327	2.92	0	.094
Do	Beef melts 50, salt 1, white fish meal 12.25, dried skim milk 23.25, cottonseed meal 12.25, wheat flour middlings 12.25	10.0	38.1	281	3.20	0	.134

[1] The very low prices of beef melts in 1944 helped keep cost charges down.

[2] Dried milk so expensive as to make cost of production from diets containing it unnecessarily expensive. With milk at "pre-war" prices, cost of production would have been under eleven cents with this diet, and more competitive in other instances.

that under the experimental conditions as high as 59 percent of raw starch might be digested. The experiments also showed that about 20 percent more of cooked starch was utilized under similar conditions. It is probable, however, that a much smaller percentage of either raw or cooked starch would be digested under ordinary feeding conditions.

An interesting result of the experiments was the discovery that after 16 weeks the bodies of brook trout maintained on diets rich in sucrose, dextrin, or cooked starch were greatly swollen and the fish behaved listlessly. On dissection, the livers were found to be several times their normal size and very light in color by reason of excessive amounts of glycogen present. Later experiments led these workers to conclude (Tunison *et al* 1943) that in addition to their effects on the liver "carbohydrates not only interfered with digestion but did not materially improve protein utilization. The trout's body is apparently better adapted to use protein for satisfying its energy requirement."

Extensive use has been made of cottonseed meal in trout rations, while soybean meal and peanut meal have been fed very little. Experiments at Leetown by J. S. Gutsell (unpublished) indicate that both soybean meal and peanut meal are better growth producers than cottonseed meal, but are less satisfactory from the standpoint of fingerling survival (table 1). When combined with white fish meal, the growth is increased and the mortality reduced. These results agree with McCay's (1940) findings that animal protein is superior to protein from plant sources.

It is believed that the use of plant meals in the diet of young fingerlings is inadvisable. This opinion is based on experimental evidence and also on the experience of years at the Federal hatcheries. With the better grades of fish meals and dried milk available at reasonable cost, it probably will not prove economical in the long run to feed plant meals to small fingerlings. Such rapidly-growing fish need relatively large quantities of food rich in proteins which can be easily digested and assimilated. With respect to older fish, the evidence regarding the value of plant meals in the diet is not so conclusive. Many hatcheries are said to be feeding such rations with satisfactory results, but there is still room for doubt whether ultimately anything is gained by such a diet. There is evidence, moreover, that fish reared on a meat and animal meal diet are more healthy and vigorous and presumably better suited for stocking purposes.

The use of fillers or bulk foods in the trout ration is now being advocated in some quarters, especially in the western United States (Donaldson and Foster, 1941). Several products are being used for this purpose, such as apple flour, citrus flour, and alder sawdust. These products have very little or no food value and are used in the trout ration for a two-fold purpose: (1) to prevent overfeeding and (2) to serve as roughage.

There is reason to doubt that overfeeding is as injurious as it was once thought to be, although there is no question that food is utilized more efficiently if fed in moderate amounts. Experimental lots of rainbow trout at the Leetown station have been overfed continuously for several years without any ill effects, except that the fish were exceptionally fat and the eggs of poor quality (Gutsell, 1940). In experiments by Gutsell (unpublished) using apple flour, citrus flour, and tomato flour as fillers, the fish made a much slower growth than on the same diet without the bulk foods. It is evident that fillers should not be used when rapid growth is desired, but it must be conceded that the use of bulk foods may be desirable in some cases, especially in rearing salmon fingerlings in which rapid growth is of secondary importance.

The use of roughage in the trout diet is by no means new, having been advocated by trout culturists for years. This is based on the well-known fact that the natural food of trout, consisting principally of insects and crustaceans contains a large percentage of indigestible material. It is only natural to assume therefore that artificial diets should contain a similar amount of roughage. This assumption, however, is not borne out by feeding experiments, which have failed to yield any clear evidence that roughage is necessary in the trout ration. It should be pointed out in this connection that certain products, such as cereals, shrimp bran, and similar foods, which have been much used in trout rations do furnish considerable roughage. It is possible, also, that further studies may show that roughage has a more important function than available information indicates.

FEEDING METHODS

Meat and other foods should always be ground fine enough to be readily swallowed by the fish, but this is a matter that can be easily overdone. When the advanced fry begin feeding, there is little danger of getting the food too fine, and it should be forced through the finest plate of a grinder several times in succession. As the fish increase in size they are able, of course, to swallow larger particles, and, if the food is not ground so fine as at first, they will take it more readily and lose less in the surrounding water.

In feeding small fingerlings most fish culturists add a small amount of water to the food, so that the particles will separate readily in the water. However, some insist that it is better to place small portions of food at intervals on the bottoms of the troughs, where the fish can break it up at their leisure. If carefully done, there is probably less loss by the latter method, but it is questionable whether all the fish have an equal opportunity to obtain food.

When the fish begin to take food, it is customary to feed them 5 or 6 times a day, but as they grow older, the number of feedings may be decreased gradually, and 2 meals a day are sufficient for the larger fingerlings. Older fish are usually fed once a day, although when very rapid growth is desired, it is probably better to feed both in the morning and in the evening. Of course, when the fish are fed twice a day, it is not advisable to feed as much at one time as when they receive only 1 meal in 24 hours. Needless to say, the food should always be distributed over a considerable area, so that all the fish will have an equal opportunity to get a share. In feeding fish of any age, it is always a good rule to give them only as much food as they will eat readily. It is poor practice to allow food to accumulate on the bottom of the trough or pool, because not only is such food a total loss, but it will soon begin to decay and cause trouble.

When trout are to be handled or transported, it is always advisable not to feed them for some hours previously. This serves a twofold purpose: there will be less excrement to accumulate in the cans and cause trouble, and the fish will stand handling better.

IMPROVEMENT OF STOCK

One of the most important phases of trout culture and one that, remarkably enough, has received relatively little attention, is the necessity for improvement of the brood stock in order to obtain the best results. Everyone recognizes that continuous and rigid selection is necessary in the case of domesticated animals and plants, but few seem to have realized the importance of this principle in trout culture. Indeed, the tendency in many cases has been in the opposite direction, for some of our commercial growers have marketed their best and largest fish and saved the remainder for breeding purposes. On the other hand, some trout culturists have taken pride in building up a superior stock of brood fish, but usually they have not systematically carried on the selection over a term of years, as must be the case if permanent results are to be obtained.

According to Hayford and Embody (1930) breeding experiments with brook trout started in 1919 at the New Jersey State Hatchery at Hackettstown, resulted in a marked increase in the rate of growth and in egg production, as well as greater resistance to disease. In four generations the maximum length of fish at the end of the second year increased from 10 inches to 13.75 inches, while the minimum length increased from 7 to 10.5 inches. They state that it is now possible at the end of the first year to have trout for stocking purposes which average between 6 and 7 inches long, instead of the usual 3-, 4-, or 5-inch fingerlings. These results were accomplished by selecting for breeding purposes a small percentage of the most rapidly growing fish in each generation.

The breeding experiments with brook trout conducted at the Pittsford (Vt.) Experimental Hatchery for several years were carried on in a somewhat different manner. Each season, selected fish were mated and the progeny of each pair reared separately during the following summer. In selecting these fish, special emphasis was placed on rapid growth, vigor, fecundity, body symmetry, and coloration. Owing to the lower temperature of the water the fish did not grow so rapidly or mature so quickly as at Hackettstown, and progress therefore was considerably slower.

It was found that the young from a single pair are usually much more uniform in size than fish of mixed parentage; and that the offspring of different pairs showed marked differences in the rate of growth under practically identical conditions. In some lots the growth during the first summer was two or three times that of other lots. This was true even though the parent fish might differ but little in size or other characteristics. It is also worthy of note that the young of certain parents showed much smaller losses than the young of other pairs which seemed to be equally vigorous.

Several lots of fingerlings representing the third generation of selected fish showed a more rapid growth than those of the 2 preceding generations, and also greatly outgrew fingerlings from the general brood stock. The best fish from the latter showed an average individual weight on September 3 of 6.09 grams, while 1 lot of selected fish on the same diet averaged 12.7 grams in weight on September 7; another lot had an average weight of 12 grams and several lots averaged 10 grams or more. These results are the more striking when it is considered that the general brood stock had been improved by mass selection during this time so that the average weight of fingerlings kept on a diet of beef liver through the summer had more than doubled.

In order to obtain a fair comparison of the growth of selected and nonselected fish, 3 lots of brook trout fingerlings were reared at the Leetown Station under as nearly identical conditions with respect to food and water supply as possible. Each lot contained 1,200 fingerlings and was placed in a standard hatchery trough on March 1, where the fish remained until the experiment was discontinued. Two lots of fish were from eggs taken at the York Pond (N. H.) Station. One lot of these eggs was from fish that had been reared from wild stock; the second lot from fish still farther removed from their original wild ancestors. The third lot of eggs was taken from selected stock at the Pittsford Station. The results of this experiment are shown in figure 5.

It will be noted that from the beginning of the experiment the fish from the Pittsford stock grew much more rapidly than those from the York Pond Station, but there was practically no difference in the growth of the 2 lots of fish from the latter station. The experiment was discontinued in August, when the fish in each lot were 29.5 weeks old. At this time the average weight of the Pittsford fish was 14.7 grams, while that of the 2 lots from York Pond was 4.9 grams and 4.6 grams, respectively. There was also a marked difference in mortality in favor of the Pittsford fish, although the losses were abnormally high in all 3 lots. This was no doubt largely due to the fact that no attempt was made to lessen the mortality by the use of control measures.

The increase in egg production as a result of selective breeding is equally gratifying. The average number of eggs produced at the end of the third summer (that is, from fish commonly known as 2-year-olds) was 958 in 1928, and after selective breeding, 1,779 in 1932. These fish were selected as the best available fish of their age.

An unexpected result was the accumulation of data showing that the date at which trout spawn is primarily determined by heredity. It was also found that while mixed lots of fish continued to spawn for several weeks, those with a common ancestry usually had a much shorter spawning season and in some instances were all ready to spawn at practically the same time (Davis, 1931).

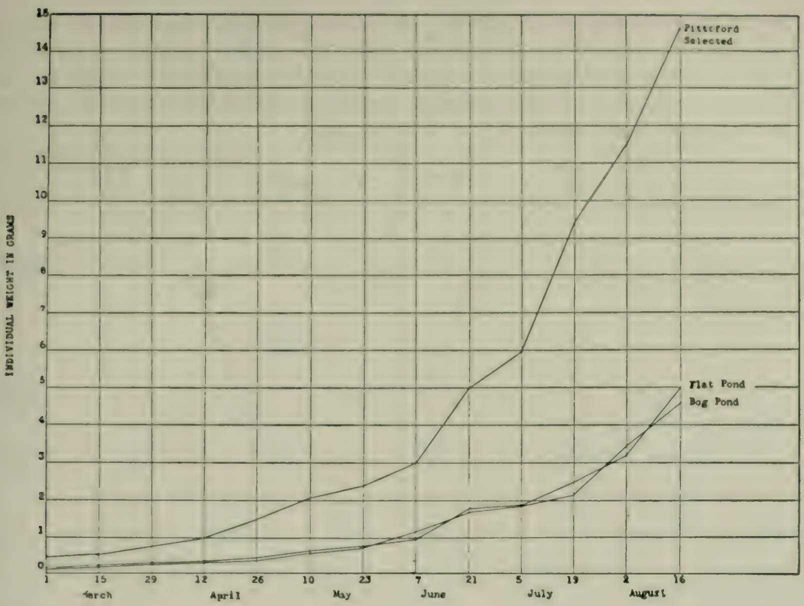

FIGURE 5.—Growth curves showing the effect of selective breeding on brook trout.

Moreover, these fish continued to spawn on the same date in each succeeding year.

Evidence has also been obtained indicating that it will be possible to develop a strain of brook trout more resistant to furunculosis than are the average fish of this species. Two lots of fish from mated pairs have shown a marked resistance to the disease, the percentage of survivals being much greater than in any other lots. Owing to the fact that it is very difficult to eradicate furunculosis after it has become established at hatcheries, the development of a resistant strain of fish offers one of the most promising means of combating the disease.

There is considerable evidence to show that, in general, much better results can be obtained when a hatchery produces its own eggs than when the eggs are obtained from outside sources. This appears to be due to differences in the environment and indicates that eggs produced under certain conditions will develop much better and produce more vigorous young under the same conditions than when transferred to a different environment. Conditions at trout hatcheries vary widely as regards temperature of the water, dissolved minerals and gases, and other factors. In spite of such variations, experience has shown that most of them provide favorable conditions for trout, and it would be impossible in many instances to say which conditions are best for trout culture. Undoubtedly, trout can flourish under a wide range of environmental conditions, but it does not follow that fish which have become acclimatized to one set of conditions can withstand an abrupt change to a quite different environment without detrimental effect. This has been very noticeable at the Pittsford Experimental Hatchery, where eggs of brook trout from several sources have been hatched in adjoining troughs and the young reared under virtually identical conditions. In nearly every instance the local fish have suffered much smaller losses from various diseases than those hatched from eggs produced elsewhere. There have also been noticeable differences in this respect among fish hatched from eggs from different outside sources. There is no reason to believe that the diseases in question were brought in with the eggs, as they have been prevalent at this hatchery for years. The most logical explaination is that the vigor and vitality of the fish were affected by the changed conditions.

In view of these facts, it is evident that for best results the trout culturist should produce eggs from carefully selected stock in his own hatchery. Of course, it is recognized that in many instances this, for one reason or another, may be impracticable. In such cases it will probably be found that eggs from certain sources usually do better than those from others, and the trout culturist can govern himself accordingly.

PARASITES AND DISEASES

GENERAL CONSIDERATIONS

The parasites and diseases of trout constitute one of the most important problems with which the fish culturist has to deal. Wild trout are but seldom seriously affected by disease caused by the presence of parasitic organisms. No doubt this is due primarily to the conditions under which they live. The swift, cold waters of the typical trout stream are about as poorly adapted to the development and diffusion of trout parasites as could be imagined. The wild trout that are injured by parasites and infectious diseases are ordinarily fish living in ponds or lakes, where conditions are more conducive to the spread of parasites. There is no reason to believe that the various parasites and diseases that are found at hatcheries have developed as a result of the domestication of trout. Undoubtly they all occur to some extent in wild fish, to which they ordinarily cause little or no injury; but when the fish are crowded together in hatchery troughs or pools, there is every opportunity for the rapid increase and spread of parasitic organisms and diseases to which trout are susceptible, resulting in the outbreak of epidemics with consequent heavy losses. Of course, this is simply another application of the well-known principle that in the domestication of animals and plants man is, to a certain extent, running counter to natural laws, with the penalty of eternal vigilance that this entails.

The control of these parasites and diseases is a problem of the greatest importance, and no trout culturist can hope to cope with them successfully unless he is familiar with the more essential facts. In the following pages, no attempt has been made to deal with the subject in a technical or exhaustive manner. On the contrary, the sole object has been to give the essentials regarding each disease in terms as nontechnical as possible, so that the fish-culturist may be prepared to deal with it intelligently should the necessity arise, as no doubt will frequently be the case.

The great majority of the infectious diseases of trout are caused by either bacteria or protozoa. As is well known, the bacteria are very minute organisms classified as plants although they possess many characteristics which differ widely from those that in the popular mind are commonly associated with plants. On the other hand, the protozoa are regarded as animals; but here, again, one must note that they are very different from the popular conception of an animal. The protozoa are all very small, although larger and more highly organized than the bacteria. Some of the larger protozoa are visible to the naked eye, but the great majority are strictly microscopic, and some are visible under only a comparatively high magnification. The only characteristic that the protozoa can be said to possess in common is that they are all composed of only a single cell, although even in this respect, as in the case of the Myxosporidia which are characteristic fish parasites, the distinction sometimes breaks down. Of more importance from the practical standpoint is the fact that the protozoa are usually very delicate organisms easily killed by drying or by chemical agents. Many of them have a very complicated life history, a knowledge of which is essential to the devising of effective methods of control.

In addition to bacteria and protozoa, the parasites of trout include several species of worms, but these are usually not as injurious as the former. In fact, *Gyrodactylus* is the only parasitic worm that ordinarily has to be considered by the trout culturist. Belonging to quite a different group is the parasitic copepod *Salmincola,* which is a member of the great group of crustacea, a group that includes the waterfleas, crabs, crawfishes, and shrimps.

Among the plants the only common parasites, aside from bacteria, that affect trout are the water fungi (Saprolegniaceae) which, under certain conditions, may attack fishes. As fungus is always easily recognized, infections by this parasite have assumed an importance among fish-culturists out of proportion to its actual potentialities for harm. Usually the appearance of fungus is an indication of the presence of some less conspicuous and more insidious agent, which is the real cause of the trouble. In other words, the appearance of fungus is a warning signal that no fish-culturist should disregard, but which in itself may be relatively unimportant.

It not infrequently happens that fish are affected at one time with two or more entirely distinct diseases. This, of course, complicates the situation, and results not only in a much higher mortality than would otherwise be the case, but also greatly increases the difficulties of control.

GENERAL PRINCIPLES OF DISEASE CONTROL

From the practical standpoint, whether any particular parasite is external or internal is of the greatest importance. If it is an external parasite — that is, lives on the body, fins, or gills of the host — it is possible in most cases to apply some chemical that will destroy the parasite without serious injury to the host. Many substances have been employed for this purpose, the most widely used being a solution of common salt (sodium chloride). This is a fairly effective treatment for such delicate organisms as protozoa and fungi, but even under the most favorable conditions, a few of the parasites survive and the treatment must be repeated at frequent intervals. In common hatchery practice, the salt is simply distributed throughout the trough, the water supply having previously been cut off. When the fish begin to show signs of distress and turn on their backs or sides, the water is again turned on and the fish quickly recover. As it is impossible to control accurately the strength of the solution under such conditions, a better method is to dip the fish for a short time in a 3 percent solution. This method requires less salt and the treatment is easier to control. The solution should be renewed frequently, since it soon loses its effectiveness.

Other chemicals used extensively for killing external parasites are copper sulphate, potassium permanganate, acetic acid, and formalin. Copper sulphate and potassium permanganate are especially indicated when dealing with bacterial infections, but the latter is also effective against protozoa and flukes (Trematoda). Formalin and acetic acid are of value in treating fish infected with animal parasites, but are not effective in bacterial infections.

The most common method of treating fish for external parasites is the dipping method, in which fish are immersed in a relatively strong solution of the chemical for a very short time. To use this method most efficiently, the fish should be removed from the trough or pool in a net and turned into a tub or similar vessel containing the solution. This allows the fish to swim about freely in the solution and all parts of the body are equally exposed to the chemical. If large numbers of fish are treated at one time, the solution should be frequently aerated. After the fish have been exposed to the solution for the required length of time, the contents of the tub should be poured through a net and the fish placed immediately in running water. In this way the maximum effect of the treatment is obtained with the least injury to the fish.

In treating trout with copper sulphate a solution of 1 part copper sulphate (by weight) is dissolved in 2,000 parts of water. The fish should be dipped in the solution for 1 or 2 minutes and then transferred at once to running water. They will at first show very evident signs of distress, but in most cases will fully recover in a short time. Even small fingerlings, unless they have been previously weakened by disease, are not permanently injured by the treatment if it is carried out properly. If the disease is well established, many of the fish may be so weakened as to be killed by the treatment, but such fish would undoubtly have died in any event. Healthy, vigorous trout will survive for several minutes immersion in a 1 to 2,000 solution of copper sulphate.

According to Ellis (1937), copper sulphate and salts of other heavy metals as well as certain acids injure fish by combining with the mucus covering the body and gills to form an insoluble compound which seriously interferes with respiration. Consequently, the fish die from asphyxiation, and not from toxic poisoning. Since salt is effective in removing mucus, it is frequently used in connection with the copper sulphate treatment to lessen its injurious effects. For this purpose the salt may be added to the copper sulphate solution or the treatment may be followed by a salt bath.

If a galvanized vessel is to be used for the solution, it should first be painted on the inside with asphaltum or some similar substance to prevent any chemical action between the copper sulphate and the walls of the vessel. It is more convenient to use the pulverized form of copper sulphate, which dissolves very rapidly, so that the solution is immediately ready for use. To guard against deterioration it is always advisable to make up a fresh solution just before it is to be used. The solution rapidly becomes weakened with use and consequently should be renewed frequently.

Copper sulphate will quickly precipitate out of solution in hard water and its efficiency as a disinfectant is thus greatly impaired. This can be prevented by adding acetic acid drop by drop after the white flocculent precipitate has formed until the solution regains its clear blue color. Care should be exercised to prevent the addition of any excess acid.

The strength of the copper sulphate solution that can be used with safety varies considerably in different types of water. For this reason, if one has had no previous experience with this chemical in the water in which the fish are to be treated, it is advisable to experiment first with a few fish to determine the strength of the solution that they can withstand without serious injury. In most waters a 1 to 2,000 solution will not seriously injure healthy fish, but in some very soft waters copper sulphate in this proportion is said to have caused excessive losses. It should also be remembered that chemical solutions act more quickly at high temperatures, and the length of the treatment should be shortened accordingly. In any event the fish will probably be "off their feed" for a day or so following the treatment.

While the dipping method is efficient and not unduly laborious for the treatment of fish in the hatchery, it nevertheless involves much handling, which, especially where several treatments are required, may be decidedly injurious. The evil effects of handling are much more pronounced when the fish are held in pools or raceways from which they must be removed by a seine. In fact, dipping the fish under such circumstances is so difficult and injurious that in many instances it is doubtful if it is worth while. This difficulty of treating fish in raceways or pools is one of the strongest arguments that has been advanced against their use for young trout.

For these reasons, methods for the treatment of fish without removal from troughs or pools have received much attention. Kingsbury and Embody (1932) have devised a method whereby a very dilute solution of potassium permanganate or copper sulphate is allowed to flow through the hatchery troughs for a period of 1 hour or more. This method, of course, obviates all handling of the fish, but is complicated and does not lend itself readily to the treatment of fish in pools or raceways.

Fish (1933) has devised a much simpler method, which is especially applicable to raceways and pools. The essential part of this device is a U-shaped siphon mounted on a block of wood which floats on the surface of the water. The length of the arms of this siphon should be about 12 and 14 inches, respectively. The shorter arm is inserted in a hole in the float, while the longer arm hangs down outside the container. Variations in the amount of water delivered by the siphon are obtained by using glass tubing of different diameters. In most cases it is necessary to use only one siphon, and proper concentration of the chemical in the pool is obtained by adjusting the strength of the original solution to the volume of flow. An even simpler device is to immerse the neck of a large bottle filled with the solution in a shallow pan in which the solution is automatically kept at a constant level. This is the principle employed in the ordinary kerosene cooking stove with which everyone is familiar. To obtain a uniform flow of the solution at the required rate it is necessary only to attach a tube with the required diameter to the pan. The dilutions to be used are those recommended by Kingsbury and Embody, that is, 1 part copper sulphate to 100,000 parts water, or a 1 to 150,000 solution of potassium permanganate. The fish should be exposed to the disinfecting solution for 1 hour, after which it should be washed out as quickly as possible by increasing the flow of water through the pool.

The application of chemicals to ponds or troughs while water is allowed to flow through them in the usual manner presents many difficulties, and it is almost impossible to insure that all the fish will be exposed to the proper concentration of the chemical for the required length of time. This objection can be avoided by stopping the flow of water during the treatment. In that case it is necessary only to determine the volume of water in the pond and to add the amount of chemical required to produce the desired concentration. There is the disadvantage, however, that when the fish are crowded the oxygen may be exhausted before a full hour has elapsed, but it appears that this danger is not so great as is generally believed. If a deficiency of oxygen does occur, it may be corrected by artificial aeration or by circulating water through the pond by means of a pump.

The formalin treatment as developed by Fish (1940, 1940a) is especially designed for treating fish, after the flow of water has been stopped and is undoubtedly the most effective means yet devised for ridding fish of external protozoan parasites and gyrodactylid worms. It should be emphasized, however, that it is of little or no value in combating bacterial infections. The concentration recommended by Fish is 1 part formalin to 4,000 parts water. The fish should be kept in the solution for 1 hour, which is sufficient to kill all the parasites. This treatment will not injure the fish to any extent unless they are already in a greatly weakened condition. According to Fish, infection with animal parasites can be prevented by treating the fish for 1 hour with a 1 to 6,000 solution of formalin at bi-weekly or possibly monthly intervals.

The formalin treatment is not only more effective, but it is also much cheaper than the ordinary salt treatment. The only drawback is that formalin diffuses very slowly through the water and special precautions must be taken to obtain a uniform concentration. This can be done by first diluting the formalin with water in a pail or tub and then spreading the mixtures as evenly as possible over the surface of the pond. Fish has found that the best results are obtained by first diluting the formalin 1 to 100 and then applying with an ordinary spray pump.

The control of diseases caused by internal parasites presents a very different problem, because in most cases it is impracticable to attempt the use of medicines. Good results sometimes follow a change in the diet or the addition of some such substance as cod-liver oil to the food, but in general the successful control of such diseases must depend almost entirely on prophylactic measures. It is most important to keep the fish in as healthy and vigorous a condition as possible by providing suitable quarters with an abundant supply of cold, well-aerated water. Overcrowding should be avoided, and, of course, the greatest care should be exercised to provide a suitable diet. Every precaution should be taken to guard against infection from any source, and any implements or vessels that might possibly carry infection should never be used with healthy fish, unless they have been thoroughly sterilized.

If possible, fingerling trout should not be held in water that has previously come in contact with older fish. Yearling and older trout are usually not so seriously affected by parasites as are fingerlings, and thus may act as carriers without showing any evidence of infection themselves. For this reason, from the standpoint of disease, a spring-water supply which contains no fish is greatly to be preferred. In many sections of the country, however, there are no springs of sufficient volume to supply a hatchery, and the water must be taken from a stream. Of course, stream water can be sterilized before use, but in most cases, owing to the large amount required, this is not practicable. The danger of infection from a stream supply can be lessened, to some extent at least, by using a larger flow of water than is otherwise necessary, which tends to reduce the effects of overcrowding and to keep the fish in a more vigorous condition. Moreover, there is some evidence that stream and lake water may have desirable qualities, especially for brown trout and landlocked salmon, which are not present in water taken directly from springs. This brings up the problem of so-called "conditioned water," which has received very little attention from fishery biologists. The term "conditioned water" has been given to water in which animals have lived and which consequently contains various products, largely excretory, contributed by the conditioning animals. Such waters have been shown (Allee *et al,* 1934; Evans, 1936) to contain some growth-promoting factor that was absent in water which had not been biologically conditioned.

Of course, the precautionary measures just mentioned are fully as important in the case of external parasites as in combating diseases caused by internal parasites, but they are emphasized here because they are virtually the only measures known for dealing with diseases of the latter type. In treatment of diseases the trout culturist must exercise eternal vigilance and be quick to recognize the first indication of an outbreak. Half the battle lies in the ability to diagnose a disease in its early stages and to adopt appropriate measures for its control before it is too late.

STERILIZATION OF PONDS AND RACEWAYS

For the sterilization of ponds and raceways when large quantities of disinfectant are required, freshly slaked lime (calcium hydroxide) is, if properly applied, both cheap and effective. It can be used in the form of a powder, or preferably as "milk of lime" (1 part slaked lime to 4 parts of water). In disinfecting with lime, the pond should first be drained and the milk of lime applied as a spray over the bottom and sides. Special attention should be given to the inlet and outlet of the pond to make sure that the solution is forced into all cracks and crevices. If possible the pond should be allowed to dry in the sun for several days after being sprayed with lime. It should be emphasized that calcium hydroxide unites with carbon dioxide in the air or water to form calcium carbonate which has no antiseptic value, and for that reason should be freshly prepared shortly before it is to be used.

There are obvious advantages in sterlizing a pond while it is filled with water. For this purpose it is necessary to use some powerful disinfectant which is effective in a very dilute solution. Copper sulphate and potassium permanganate are frequently used, but under ordinary conditions it is believed that chlorine is much superior (Connell, 1939; Davis, 1938; Hagen, 1940). However, if exceptionally large amounts of organic matter are present, creating a high chlorine demand, copper sulphate may prove more effective.

If the ponds or raceways to be disinfected are small, the most convenient source of chlorine is calcium hypochlorite (bleaching powder) which comes in the form of a manufactured powder guaranteed to contain not less than 70 percent of available chlorine. The chlorine is released when the powder is dissolved in water. For use in sterilizing ponds, the pond should first be drained and the powder spread on the bottom near the inlet so that the water passes over it as the pond is filled. The amount of clorine dissolved in the water can be determined by a Hellige chlorine comparator using orthotolidine as the indicator. The addition of a solution of orthotolidine to water containing free chlorine produces a colored solution extending through different intensities of yellow to a clear reddish brown. Since the intensity of the color is proportional to the amount of chlorine present, the chlorine content can be determined by comparison with color standards. Ordinarily, 5 p.p.m. (parts per million) should be sufficient to kill all harmful bacteria and other organisms if the solution is allowed to remain in the pond for several hours.

The Hellige comparator is somewhat expensive, and if only a small amount of disinfecting is to be done, its purchase may not be justified. In the absence of a comparator, a rough method is to add a few drops of orthotolidine solution to the water in a test tube or small bottle. A deep yellow or reddish brown indicates the presence of sufficient chlorine to kill bacteria in a few minutes.

When a large amount of chlorine is required, liquid chlorine is more economical than calcium hypochlorite. Liquid chlorine can be obtained in iron cylinders containing 50 to 100 pounds of chlorine. The liquid is under great pressure and is converted into gas as it escapes from the cylinder. The gas is introduced into the water through a garden hose attached to the outlet valve of the cylinder. A section of iron pipe, closed at the free end and perforated with a large number of very small holes, is attached to the other end of the hose. In this way the gas is broken up into small bubbles which are more readily absorbed by the water. If the water enters the pond through a pipe under pressure, it is a simple matter to get the necessary amount of chlorine into solution. The hose with the perforated iron pipe is inserted into the pipe line and the required amount of chlorine is released as the water flows into the pond. The pond should, of course, have been previously drained. When the pond is supplied through a ditch or open flume, it is more difficult to get the chlorine into solution without the loss of a large percentage of the gas. If the gas is forced to bubble up through several feet of water, much of it is absorbed, but even under such conditions, it is impossible to avoid considerable waste.

According to Connell (1939) the difficulty of getting chlorine into solution in open water without excessive waste can be overcome by use of an outboard motor which churns up the water in which the chlorine is being released, breaking the gas into minute bubbles which are quickly absorbed. The outboard motor is clamped to a plank extending over the pool and the propeller should be submerged as deeply as possible. The chlorine gas is directed against the propeller from the open end of the hose.

The chlorine disappears quickly from the water, especially in direct sunlight, and if the solution is held in the pond for 24 hours before being released, it should not be injurious to fish. However, it is advisable first to test the water with orthotolidine, the absence of color indicating that no free chlorine is present. If for any reason it is desirable to drain the pond before the free chlorine has disappeared, it can be neutralized by adding a 5 percent solution of sodium thiosulphate ("hypo") to the water. The orthotolidine test will show when the chlorine has been completely neutralized.

When ordinary precautions are taken, liquid chlorine can be used with little danger, nevertheless, the operator should be provided with a gas mask for use in case of accident.

EXTERNAL ANIMAL PARASITES

TREMATODA

Gyrodactylus

One of the most common external animal parasites of trout is the small trematode worm, or fluke, belonging to the genus *Gyrodactylus*. These worms occur at virtually all hatcheries and, when abundant, may seriously injure the fish and even cause considerable mortality, especially among small fingerlings. In exceptional cases they may be present in such numbers that every part of the body is fairly covered with parasites. Usually, however, they are not sufficiently abundant to cause a heavy mortality, their presence being indicated by frayed fins and evidences of physical discomfort. It is possible that more than 1 species of these worms may infect trout, but, unfortunately, little attention has been paid to their specific characters. According to Mueller (1936) the common species on trout in this country is *Gyrodactylus elegans,* which is found also on trout in Europe. A very similar, possibly identical, species occurs on the goldfish. From the practical standpoint it is of little importance whether one or several species infest trout, for there is no reason to believe that they differ essentially in their habits or in their effects on the host. Similar parasites are common on other species of fish and may be an important factor in the propagation of warm-water fishes.

DESCRIPTION OF PARASITE

The fluke *Gyrodactylus* may occur almost anywhere on the host, but is usually most abundant on the fins, especially the dorsal and caudal fins. The affected surfaces become covered with a bluish-gray slime due to an increased secretion of mucus. Later, if the parasites are very abundant, the fins become badly frayed and may eventually be worn down to mere stubs. These lesions often become infected with fungus, so that in late stages of the disease there is frequently a considerable growth of fungus on the fins and body. *Gyrodactylus* can be easily found by scraping off some of the slime from the affected parts and examining it under the microscope. The worms will be seen in rapid movement, twisting and squirming about in every direction.

If the fish is examined in water with a hand lens, the worms can usually be seen without difficulty attached by one end to the fish and waving the body back and forth, or they may be slowly crawling about in the same manner as a measuring-worm. Fish infested with *Gyrodactylus* can often be seen rubbing themselves against the sides or bottom of the pond in an evident effort to rid themselves of the worms. In fact, this is one of the most reliable indications of the presence of the parasite.

When examined under a low magnification (fig. 6) the worm appears as a small, transparent object armed at one end with a pair of large recurved hooks. Surrounding the paired hooks is a flattened, disk-shaped structure bearing a number of small hooks on its outer margin. It is by means of these hooks at the posterior end of the body that the worm is able to cling to the host, the hooks becoming embedded in the epithelium. At the anterior end the body terminates in two short lobes.

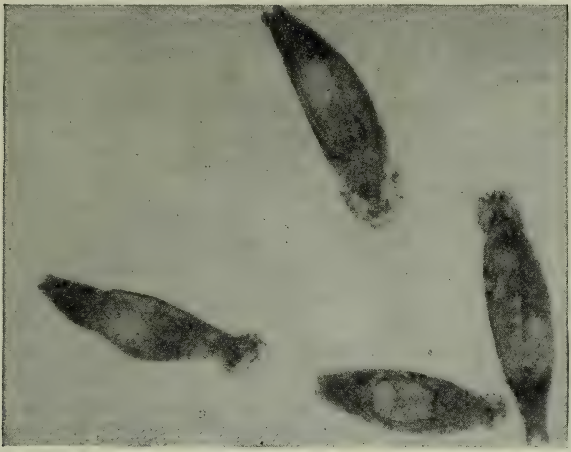

Figure 6.—Photomicrograph of *Gyrodactylus* from trout. Magnified 85 diameters.

Unlike most parasitic worms, *Gyrodactylus* does not lay eggs. On the contrary, it gives birth to living young, which are already well developed and immediately attach themselves to the host. The young in various stages of development can usually be seen within the body of the mother, the large paired hooks being especially prominent.

CONTROL MEASURES

Although *Gyrodactylus* probably occurs at all trout hatcheries, for some unexplained reason many hatcheries seem to experience little trouble from the parasite while others suffer from frequent outbreaks. Fortunately, the parasite can be easily controlled and no hatchery should suffer serious losses from *Gyrodactylus*.

Dipping the fish for 1 minute in a 1 to 500 solution of acetic acid, as first recommended by Embody (1924), is effective in ridding fish of the parasite, and was in almost universal use until recently. An even better method, however, is to dip infested fish in a 1 to 4,000 solution of formalin for 1 hour; as the fish are less injured by this treatment and all worms are destroyed. With the acetic acid dip a few worms, which are not fully exposed to the acid in the short time allowed for dipping, may survive and make necessary a repetition of the treatment within a short time.

Treatment with a dilute solution of potassium permanganate has been found also very effective in ridding fish of *Gyrodactylus*. For this purpose Kingsbury and Embody (1932) recommend a concentration of not less than 1 to 150,000 nor greater than 1 to 100,000. These concentrations will kill other external parasites such as *Chilodon* and *Trichodina*.

Discocotyle salmonis

The trematode worm, *Discocotyle salmonis*, is somewhat similar to *Gyrodactylus*, but is readily distinguishable by its much larger size and dark brown color. Unlike *Gyrodactylus*, it occurs only on the gills, and is usually crowded in among the filaments, where it is not easily seen unless a careful examination is made. The worm, which is 3 to 5 millimeters long is, however, readily visible to the naked eye. Its posterior end is modified into a flattened disk, which bears on each side a row of four suckers armed with small hooks, and thus forms an efficient attachment organ, by means of which the parasite clings to the gills and is very difficult to dislodge.

The parasite injures the fish by sucking blood from the gills and through irritation of the tissues at the point of attachment. The gills of infested fish are usually light colored, with an excessive secretion of mucus. When abundant the parasite may cause an acute anemia, which eventually results in the death of the host.

Nothing is known of the life history of this worm, but from analogy with related forms, it is probable that the eggs, surrounded by a tough resistant shell, are laid between the gill filaments of the host, where they remain until hatched. There is no evidence that *Discocotyle* has an intermediate host, as is the case with internal parasitic trematodes. It is not impossible, however, that the eggs may occasionally drop from the gills and develop on the bottom of the pond. The worms apparently develop very slowly, since trout do not become infested to any extent until they are 2 years old.

This parasite was first described by Elmer Schaffer in 1916 from rainbow trout at the State hatchery, Cold Spring Harbor, N. Y. Later it was found on brook and rainbow trout at other hatcheries, but so far as the writer is aware, it has been reported only from Long Island, where it is evidently firmly established.

CONTROL MEASURES

The acetic-acid treatment, which is so effective in the case of *Gyrodactylus*, is of no value in combating *Discocotyle*. The latter is much more resistant to the acid solution than the former and a solution strong enough to kill it usually causes the death of the host as well. Furthermore, the great majority of the worms lie between the gill filaments, where they are more or less protected from contact with any solution.

According to Laird (1927), the parasite can be successfully controlled by the use of Zonite. A solution composed of 1 part Zonite to 5 parts of water is sprayed directly on the gills of infested fish by means of an atomizer. In using this treatment it is necessary to handle each fish individually and to bend the lower jaw back so that the gills are separated. If this is not done, many of the worms will not be reached by the spray.

In Europe it has been found that a closely related species occurring on the gills of trout can be destroyed by immersing the fish for 1 to 1½ minutes in a saturated solution of common salt. It is claimed that the worms are virtually all killed, while the fish are not seriously injured by the short immersion in the salt solution.

Parasitic Copepods

The copepods are small crustaceans, the majority being free-living forms abundant in both fresh and salt water, where they form an important item in the diet of many food and game fishes.

Several species of parasitic copepods are found on trout and salmon, but by far the most common form is *Salmincola edwardsii,* which is widely distributed throughout the east and middle west. This species is the only one whose life history has been worked out, but since the other species occurring on trout are very closely related, it is not probable that their behavior and life history are essentially different from those of *Salmincola edwardsii.*

DESCRIPTION AND LIFE HISTORY

The copepod, *Salmincola edwardsii* occurs only on brook trout—rainbow and brown trout being immune. The parasite is attached to the gills or fins where it can be easily seen with the naked eye (fig. 7). It is relatively large, measuring several millimeters in length, and is yellowish white in color. Its anterior end is attached to the gills by means of a special organ developed from the mouth parts. The end of this attachment organ bears a bulb-shaped enlargement, which is inserted in the gill filaments, firmly anchoring the parasite in place. Posteriorly each copepod bears a pair of long egg sacs, within which the embryos undergo complete development. The parasite ordinarily seen attached to the gills is a female. The male is much smaller and is ususally not noticed except after special search.

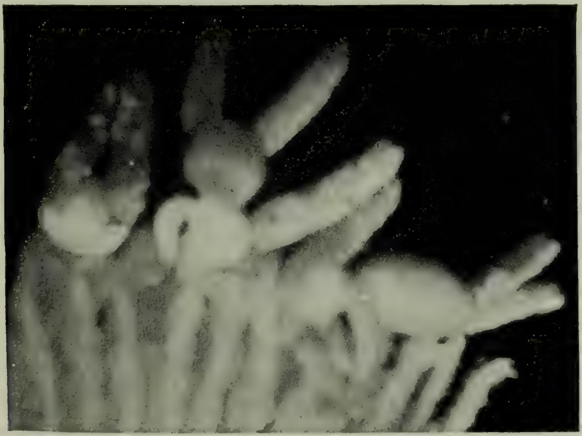

Figure 7.—Parasitic copepods *(Salmincola edwardsii)* attached to gill filaments of adult trout. Magnified 7 diameters.

When the young are fully developed the egg sacs break open and the larvae escape into the water as minute, free-swimming organisms closely resembling the free-living copepods, which form such an important constituent of the plankton. They are less than a millimeter in length, very active, and swim about with rapid, darting movements. They may remain in this free-swimming state for about 2 days, constantly searching for trout on which to attach themselves. If a suitable host is not found within this time, they are unable to develop further and soon perish.

Each larva possesses powerful mouth parts and a peculiar attachment filament, by means of which it is able to rasp a hole in the gill tissues, into which the enlarged end of the filament is inserted and soon becomes embedded. After attachment, the parasite undergoes rapid degeneration through which it loses its swimming feet and all evidence of segmentation, the abdomen becoming converted into a rounded, sac-like structure.

About 2 or 3 weeks after attachment the parasites become sexually mature. Mating then takes place, after which the diminutive males drop off and die. The females, however, live on for several weeks, increasing enormously in size and undergoing still further degeneration. The young are liberated in about a month after the eggs are fertilized. Each female ordinarily lays 2 batches of eggs, after which she dies and gradually disintegrates. Under ordinary conditions, the entire life cycle is completed in about 2½ months.

While attached to the gills, the parasite injures the fish by sucking large quantities of blood and also by mechanical injuries to the tissues, which sometimes result in secondary infections by fungus. When only a few parasites are present, they do comparatively little harm, but when they become very abundant, as is likely to be the case under the crowded conditions in hatchery ponds, the fish are greatly weakened and large numbers eventually succumb.

Usually adult fish are more heavily parasitized than fingerlings or yearlings, and the heaviest losses occur during the spawning season, when the vitality of the fish is low and they are consequently unable to resist the heavy drain on the system caused by the presence of the parasites.

Copepod parasites have been found frequently on wild trout in various parts of the country, but are apparently seldom abundant enough to cause serious injury. This can be readily understood, since under natural conditions, it is evident that only a very small percentage of the larvae would be able to attach themselves to the proper host. In hatchery ponds, conditions are different. Here the fish are crowded closely together in a limited area with a relatively small flow of water, so that there is every opportunity for the free-swimming larvae to find a suitable host, even though this must be accomplished within a short time.

CONTROL MEASURES

When once firmly established at a hatchery, this parasite is very difficult to control. The chief difficulty lies in the fact that, like most crustaceans, the copepods are covered with a tough, resistant, chitinous membrane, which is not easily penetrated by chemicals. Consequently, the parasites are uninjured by solutions that seriously affect the more delicate gill tissues to which they are firmly attached. It is, therefore, impossible to kill them by treating the fish with chemical solutions, as can be done with most external parasites. There is one exception to this statement which may be utilized to advantage: the larvae are comparatively delicate and are killed in a few minutes by a strong salt solution; consequently, they can be destroyed while in the free-swimming stage or shortly after becoming attached, without injury to the host, but this treatment is obviously of only limited application. Owing to the large volume of water flowing through trout ponds, the cost of treating them with salt is usually prohibitive, since to be effective the treatment must be continued for some time. In the case of fingerlings frequent salt baths may be used successfully to prevent the fish from becoming parasitized, but even this can be considered only a temporary expedient.

Fasten, to whose investigations we are indebted for most of our knowledge of this parasite, strongly recommends the installation of sand filters in all cases in which the parasites occur in the water supply. This will effectually prevent the larvae from being carried into the ponds. As adult trout are most heavily parasitized, Fasten also recommends that in badly infested hatcheries only 2-year-old fish be used for egg production, and that these fish be discarded immediately after spawning. Of course, this would necessitate rearing a new lot of brood fish each year, which would greatly increase the cost of the eggs. The introduction of predacious minnows into the brood ponds has also been recommended. These fish feed on the larvae of the parasite before they have an opportunity to become attached to a host.

Since in most cases, at least, such methods would be only palliative and would not result in the eradication of the parasite, it would seem in the long run less expensive to get rid of all parasitized fish and start anew. Of course, in the case of hatcheries having a contaminated water supply, such extreme measures would not be justified, unless at the same time an efficient sand filter should be installed.

References: Fasten, 1912, 1918, 1921; Savage, 1935.

Mussel Glochidia

Although the glochidia of fresh-water mussels are frequently found attached to the gills and fins of various species of fish, trout were thought until recently to be entirely free from such infestations. However, in July 1932 the writer found rainbow fingerlings in rearing pools on the Truckee River in California seriously infested with the glochidia of *Margaritifera margaritifera falcata* (Gould). This mussel is abundant in certain sections of the Truckee River, and the glochidia had evidently been carried into the pools in the water supply which was obtained from the river. Practically every fish was infested with several glochidia, which appeared as small, rounded, translucent bodies attached to the gill filaments. The glochidia were easily visible to the naked eye and in some instances were so abundant as to prevent the gill covers from closing.

The fish were suffering a heavy mortality, evidently due to the presence of the glochidia. A wild rainbow trout about 6 inches long, with the gills heavily infested, was found dead in the river. The fish in the rearing pools were said to have suffered heavy losses each year at this time which in all probability were due to infestation with glochidia.

Extensive studies of this mussel and its effects on trout were conducted at the above-mentioned rearing station by Murphy (1942) during the summer of 1941. This investigator found that the glochidia could live for 11 days after extrusion from the parent mussel without becoming attached to a fish. With heavy infections (600 to 1,200 glochidia per fish) rainbow fingerlings 42 millimeters in length suffered a heavy initial mortality within a day or two, due to interference with the circulation of blood in the gills. Deaths among rainbow fingerlings infected with less than 400 glochidia were usually the result of secondary infections by fungus or bacteria. These infections probably

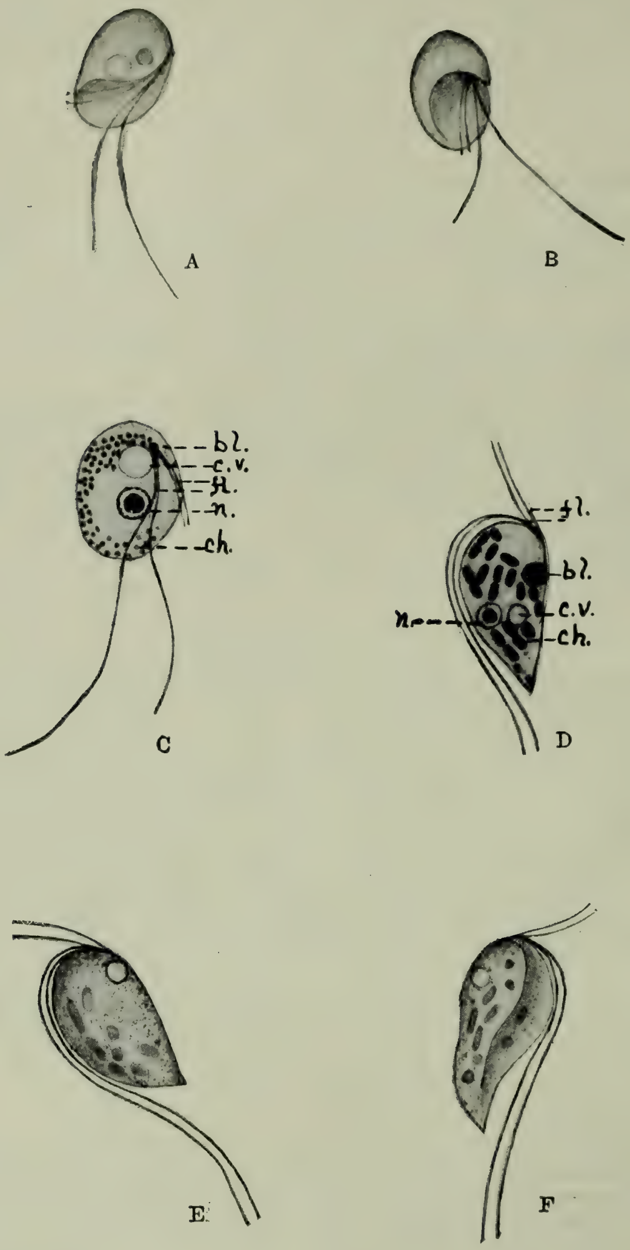

FIGURE 8.—For description, see opposite page.

started in lesions produced when the glochidia left the fish. At an average daily temperature of 57.5°F. the glochidia remained attached to the gills for 36 days and during this time increased approximately 660 percent in length.

The mussel, *Margaritifera margaritifera falcata* is found in North America west of the Rocky Mountains and other subspecies are widely distributed throughout the northern hemisphere. Murphy found that rainbow and brown trout are more susceptible to infection with this parasite than is the brook trout. Slight experimental infections were obtained in one species of sucker and two minnows, but the whitefish and sculpin were immune. In 1941 the writer found the glochidia abundant on the gills of fingerling chinook salmon *(Oncorhynchus tschawytscha)* at the Leavenworth (Wash.) hatchery. Fingerlings of the blueback salmon *(Oncorhynchus nerka)* in the same water were not infected.

CONTROL

It is impossible to destroy the parasite while on the gills with a chemical treatment, since it is entirely covered by the gill epithelium within 2 to 4 hours after attachment. Most of the glochidia can be removed by running the supply water through a filter or a settling basin, but this may be too expensive to be practicable. If possible, the water should not be used for rearing trout while glochidia are present. In most localities this period will probably include June and July.

PROTOZOA

Costia

Two species of *Costia* are known to occur on trout. The most common form is *Costia necatrix,* which was first described from European fishes, but is widely distributed also in the United States. It is not uncommon on pond and aquarium fishes and occurs rather frequently on trout as well. When abundant, it produces a disease known as costiasis, which may be quickly fatal.

According to Fish (1940), *Costia necatrix* is the most destructive of the ectoparasitic protozoans found on trout and salmon, but owing to its small size is frequently overlooked. The disease is most common where fingerling trout are overcrowded or fed an unbalanced diet, and Benish (1937) states emphatically that a severe attack of costiasis occurs only when fish have been weakened by bad living conditions.

Protozoan parasites of trout: A. *Costia necatrix* viewed from ventral side. The wide ventral groove leads to the mouth which is located near the base of the flagella. The small, rounded nucleus and the larger contractile vacuole can be seen just above the ventral groove. The short flagella lie on the floor of the groove and are difficult to distinguish. x 1,500. B. Similar to A, but viewed at an angle to the ventral side. The internal structure is not shown. Both A and B were drawn from unstained specimens killed in osmic vapor. x 1,500. C. Stained specimen of *Costia necatrix* viewed from the ventral side to show internal structure. The nucleus contains a rounded nucleolus and chromatin granules attached to the nuclear membrane. The cytoplasm contains large numbers of small, rounded granules. x 2,000. D. Side view of *Costia pyriformis* drawn from a stained specimen. The short, rod-shaped chromatoid bodies are probably bacteria. The blepharoplast which is much larger than in *C. necatrix* can be seen at the right. x 2,250. E. Side view of *C. pyriformis.* Drawn from unstained specimen killed in osmic vapor. x 2,250. F. *C. pyriformis* turned slightly toward the dorsal side to show ventral groove. In both E and F the blepharoplast appears as a clear, rounded vesicle on the dorsal side. Abbreviations: bl. blepharoplast; ch. chromatoid bodies; c.v. contractile vacuole; n. nucleus.

SYMPTOMS

Probably the most characteristic symptom of costiasis is the appearance of a light bluish or grayish film, which spreads over the body and fins. The fish lose their appetite, become rapidly weakened, and die in a short time. These symptoms, however, are not sufficiently distinctive to enable one to recognize the disease with certainty without a microscopical examination. This can easily be made by scraping a small quantity of slime from the body and examining it in a drop of water under the miscroscope, using a comparatively high magnification. The parasites, if present, can be seen as minute oval bodies darting here and there with great rapidity.

DESCRIPTION OF *COSTIA NECATRIX*

Although very small, this parasite has a complex structure which can be made out only with considerable difficulty. The body is flattened, having definite dorsal and ventral surfaces. It is from 10 to 20 microns in length and about 10 microns broad. When viewed from the flat side it is oval in shape (fig. 9, A) with rounded anterior and posterior ends. While attached to the skin or gills it is more pyriform in shape as shown in figure 9, B.

The ventral surface is concave with a deep oral groove extending from left to right across the body (figs. 8, A and 8, B). This groove is much deeper on the left side where it leads into the gullet at the anterior end. Two pairs of flagella are usually present although some individuals may have only 1 pair. One pair of flagella is much shorter than the other, extending only a short distance beyond the posterior margin of the body. The longer pair is usually 2 or 3 times the length of the body and usually unequal, 1 flagellum being about two-thirds the length of the other. These flagella are used for propelling the animal through the water and also for clinging to the epithelium of the host, while the short flagella are used for feeding. Within the body is a small contractile vacuole and a rounded vesicular nucleus which in stained specimens has a spherical, deeply staining, central body, the karyosome, surrounded by a clear unstained area (fig. 8, C).

The parasites live on the skin and gills of the fish, where they destroy the epithelial cells, apparently feeding on the fragments. Usually they are not uniformly distributed over the body, but are especially abundant near the base of the dorsal fin (fig. 9B) and on the gills, although in heavily infected fish they may be found on almost any part of the body. The peculiar distribution in patches over the body and gills may be due to the fact that as they multiply by division, the daughter individuals tend to remain attached to the epithelium and to move about very little. It is evident, however, that the parasites must break loose occasionally and thus infect other fish. They may also form resistant cysts which enable them to live for some time off the host.

During the winter of 1940 several outbreaks of costiasis at the Leetown (W. Va.) hatchery were found to be due to an undescribed species of *Costia*. This species which is described below, is more common at the Leetown station than *Costia necatrix*, and differs from the latter in several important respects.

Costia pyriformis

Costia pyriformis (Davis 1943) is smaller than *Costia necatrix*, the length varying from 9 to 14 microns and the width from 5 to 8 microns. It is distinctly pear-shaped and moves with a characteristic spiral movement which is very different from the movements of *C. necatrix*. Many individuals bear 2 long and 2 short flagella (figs. 8, E and 8, F), but frequently only 1 long and 1 short flagellum can be distinguished. A spiral groove, starting on the dorsal side at the anterior end, extends along the ventral surface, becoming wider and shallower toward the posterior end. The flagella arise dorsally at the anterior end of the groove and when the organism dies, they frequently lie along the floor of the groove. In this position the short flagella are difficult to distinguish, since they do not extend beyond the body as does the longer pair.

Stained specimens of *C. pyriformis* differ even more strikingly from *C. necatrix.* They are rounded at the anterior end, tapering posteriorly, and contain a number of rod-shaped bodies that stain deeply with chromatin stains (fig. 8, D). The nucleus can be easily distinguished as a rounded, deeply-staining body on the ventral side about midway between the anterior and posterior ends. Near the anterior end on the dorsal side is a large blepharoplast from which the flagella arise. It usually stains deeply with chromatin stains, but may stain lightly or not at all. The blepharoplast may be as large as the nucleus and can frequently be distinguished in the living organism as a clear vesicle at the base of the flagella.

In addition to the nucleus and blepharoplast, there are several deeply staining bodies which are usually distinctly rod-shaped and frequently arranged in pairs (figs. 8, C and 8, D). The bodies can be distinguished in the living animal as bright refringent granules, usually in active motion. They are probably bacteria such as are known to occur in many protozoans. A contractile vacuole is present near the nucleus.

This species attaches itself to the epithelial cells of the body and gills of the fish in the same way as *Costia necatrix,* and probably does not differ materially from the latter in either habits or life history.

CONTROL

The same methods of control can be employed with either species. It is difficult to control *Costia* with the ordinary salt bath, but good results have followed dipping in a 1 to 500 solution of acetic acid. The most effective treatment is the use of formalin as described by Fish (1940). He found that all *Costia* on the fish were destroyed by 1 treatment with a 1 to 4,000 solution of formalin for 1 hour, and that weekly treatments with a 1 to 6,000 solution of formalin were effective in preventing the fish from becoming infected with this parasite.

References: Andai, 1933; Benish, 1937; Davis, 1943; Fish, 1940, 1940b; Plehn, 1924; Savage, 1935.

Chilodon

This is a large genus containing many species, several being parasitic on fish. They occasionally occur on trout and have been known to cause serious injury to fingerlings. They are more common parasites of pond fishes than of trout and are frequently abundant on goldfish, causing heavy losses among both young and adults. The best known species is *Chilodon cyprini* which is a common parasite of gold fish. Infected fish show little evidence of the presence of the parasites until they become abundant, when the fish lose their appetite and show a tendency to lie on one side. They may also show a slight cloudiness over the surface of the body.

When an infected fish is examined with a hand lens the parasites can be seen as minute, colorless, flattened organisms creeping rapidly about over the surface of the fins, body and gills. Under a higher magnification, they appear

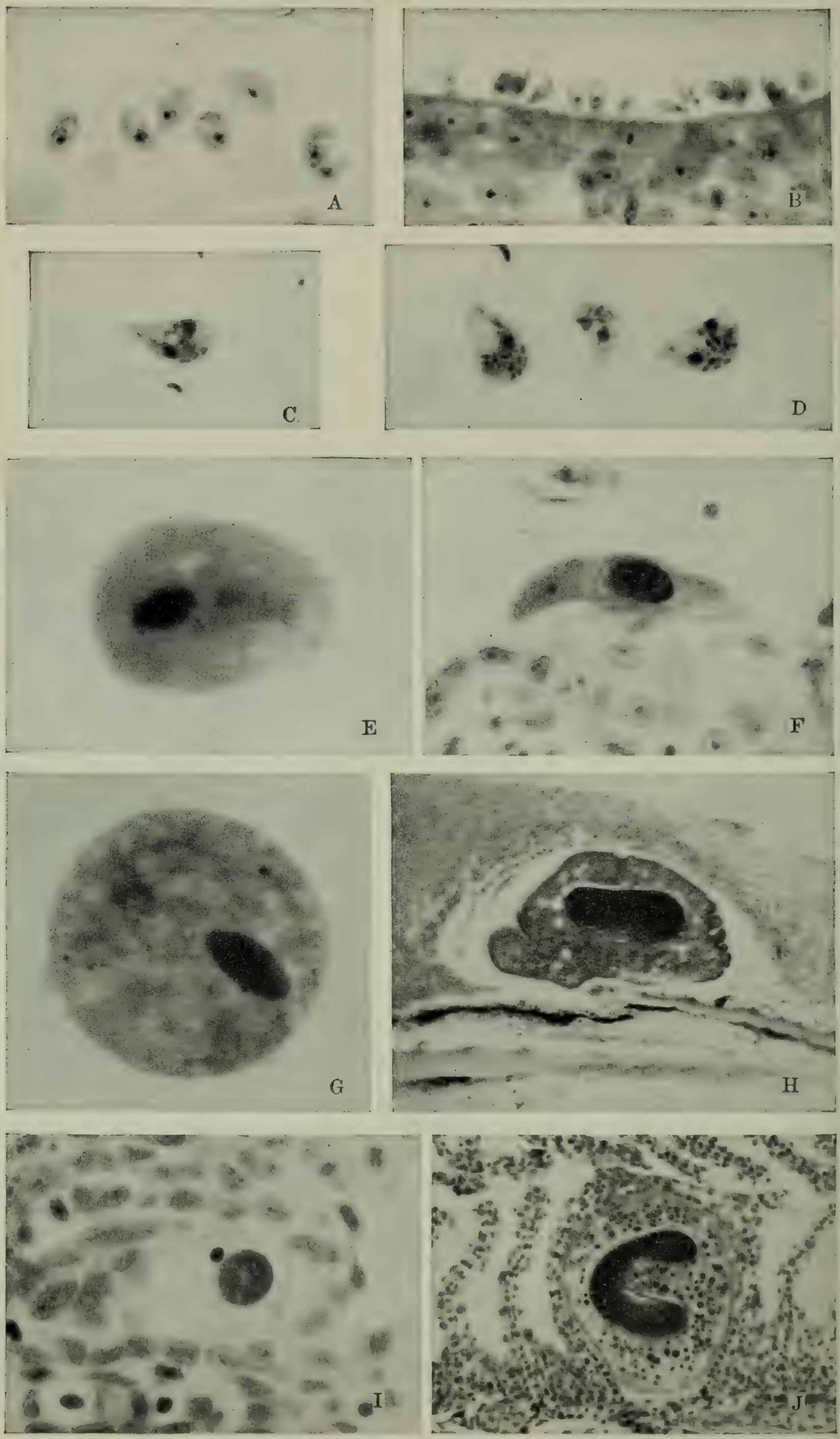

FIGURE 9.—For description, see opposite page.

more or less heart-shaped (figs. 10, B and 9, E). The ventral side is flat with cilia arranged in parallel rows. They are longer at the anterior end and are located in narrow grooves which appear as fine lines under the microscope. The number and arrangement of these grooves varies in different species. The dorsal surface is slightly convex and lacks cilia except in the oral groove at the extreme anterior end.

The mouth is located on the ventral side near the anterior end and is surrounded by a number of horny rods which extend for some distance into the body and gradually disappear. There is a large ovoid macronucleus in the posterior third of the body and a small micronucleus which is probably enclosed in the macronucleus in some species. Two contractile vacuoles are present about one-third of the distance from each end of the body, but on opposite sides.

Although these parasites are often abundant over the entire body of a goldfish, on trout they appear to be confined largely to the gills and fins. They do not appear to injure the host appreciably unless present in large numbers, but when numerous, may be the cause of serious mortality among small fingerlings.

Chilodon can easily be controlled by dipping the fish for a short time in a 3 percent solution of common salt or in a 1 to 500 solution of glacial acetic acid. An even more effective treatment is a 1 to 4,000 solution of formalin for 1 hour. One treatment by the formalin solution is sufficient, but if salt or acetic acid is used, it may be necessary to give a second treatment on the following day. Since the parasites readily leave the host, the trough or pond should be sterilized if the fish are removed for treatment.

References: Moore, 1924; Plehn, 1924.

Trichodina (Cyclochaeta)

These parasites were formerly assigned to the genus *Cyclochaeta,* but as pointed out by Mueller (1932), should be included in the genus *Trichodina,* since, so far as is known, they all lack the ring of cirri that characterizes the former genus. These protozoans are common parasites of fish and occur on a great variety of species. They are more common on warm-water fishes than on trout, but nevertheless are abundant at many trout hatcheries and may cause serious injury to fingerling trout.

Photomicrographs of protozoan parasites of trout: A. *Costia necatrix* photographed from whole mount. Each contains a nucleus with large, rounded endosome. x 860. B. *C. necatrix* attached to skin of channel catfish. Photographed from section. x 680. C. and D. *Costia pyriformis.* The saddle-shaped blepharoplast can be seen on the dorsal side near the anterior end. The rounded nucleus is located near the ventral side with rod-shaped chromatoid bodies between it and the blepharoplast. Photographed from whole mounts. x 1,270. E. *Chilodon* sp. from smallmouth black bass viewed from ventral side. The striations can be seen indistinctly on each side of the deeply stained macronucleus. The cytopharynx is visible near the anterior end at the right. x 680. F. Cross-section of *Chilodon cyprini* attached to gill of goldfish. The alternating ridges and furrows which appear as parallel striations can be seen on the ventral side at the right of the macronucleus. x .680. G. Young stage of *Ichthyophthirius multifilis* which has been dislodged from its position in the epithelium. The minute micronucleus can be seen attached to the lower side of the macronucleus. Photographed from a whole mount. x 340. H. Section of skin of bluegill sunfish with *I. multifilis* in the epithelium. The wrinkled surface of the body is characteristic. Sections of 2 scales can be seen just below the parasite. I. Small *I. multifiliis* which has recently penetrated into the gill epithelium. Note the small deeply stained micronucleus which at this stage is not attached to the macronucleus. x 330. J. Somewhat later stage with a large, U-shaped macronucleus. The parasite has greatly increased in size and is forcing the lamellae aside. The micronucleus is now located within the macronucleus. The ectoplasm can be seen as a dark line surrounding the endoplasm which is filled with rounded metaplastic bodies. x 170.

It is evident that several species of *Trichodina* occur on trout, most of them undescribed. It is also apparent that they are not always restricted to a single kind of host fish, the same species of *Trichodina,* in some instances at least, being found on very different hosts. For instance, the one shown (fig. 12, I) occurs on black bass and other warm-water fishes, but has also been found on trout. *Trichodina truttae* (fig. 12, J) described by Mueller (1937), occurs on the gills of cut-throat trout at various Oregon hatcheries, and is probably the species found by Richardson (1937) on brook trout from a Canadian hatchery.

Trichodina myakkae (figs. 10, E, 10, F, and 12, G) was described by Mueller (1937) from the largemouth black bass, but has been found on the gills of trout at the Leetown (W. Va.) hatchery.

DESCRIPTION AND LIFE HISTORY

The trichodinids have a very complicated structure, the details of which can be made out only after careful preparation and under a high magnification. In general the body is saucer- or bell-shaped, the concave lower side being used for attachment to the host. The convex adoral side is smooth and bears 2 parallel rows of cilia known as the adoral spiral (fig. 10, C). The adoral spiral usually makes a complete circuit of the adoral surface and leads into the mouth at one side. Around the margin of the disk-shaped body is a band of long cilia known as the ciliary girdle. It is by means of these cilia that the organism moves over the surface of the body and gills.

The adhesive disk on the lower or aboral side is a holdfast organ by means of which the parasite clings to the host. It is composed of a complicated skeletal structure (fig. 12, E) arranged in the form of 3 concentric rings. The inner and most conspicuous is the denticulate ring which is made up of a series of horny elements or denticles arranged like beads on a necklace. Each denticle is shaped like a hollow cone with the smaller end inserted into the cavity of the adjacent denticle, an arrangement admirably adapted to provide both strength and flexibility. On the outer side each denticle bears a flattened blade-like structure known as the hook. On the inner side of the denticle is a tooth-like process, the ray, which projects toward the center of the disk. There is great variation in the number and shape of the denticles and, consequently, they are of great value in differentiating between the various species. Overlapping the hooks on the aboral side and extending toward the margin of the disk is a circular, ribbon-like structure known as the striated band. When viewed from the lower surface of the disk it appears as a series of radiating lines extending from the denticulate ring to near the edge of the disk. In sections it can be seen that these lines are in reality long slender rods (fig. 10, C). External to the striated band is a thin striated border membrane which is usually bent downwards so that its edge is in contact with the surface of the host (fig. 12, F).

Within the body is a large horseshoe-shaped macronucleus, a small, rounded micronucleus, a large contractile vacuole, and several food vacuoles.

The parasite multiplies by binary fission which results in the formation of 2 daughter individuals like the parent. The skeleton, of course, contains only one-half the number of parts present in the parent and the original number is restored by an interesting and complicated process. Figure 12, I shows the adhesive disk of a young individual just formed by binary fission. The denticulate ring and striated band are just closing. The series of overlapping plates in the striated band is the beginning of a new denticulate ring which will replace the old as it is resorbed. Each plate will develop into a denticle and since there are two plates for each denticle of the old ring, the original number will be restored. The original number of rods in the striated band is restored by a different method. Figure 12, H is the adhesive disk of a young trichodinid in which new rods can be faintly seen between the old rods. The adhesive disk of an adult of the same species is shown in figure 12, E. Sexual reproduction by conjugation is common among trichodinids.

PATHOLOGY

The trichodinids are among the most common protozoan parasites of fish and have been the cause of serious mortalities among trout and pond fishes at hatcheries. They occur on the body, fins, and gills and under the hand lens appear as small, circular transparent animals moving rapidly about over the surface by means of the cilia at the margin of the disk.

Trichodiniasis, the disease caused by these parasites, is characterized by the appearance of white, irregular blotches on the head and dorsal surface of the body. The fins may also become badly frayed in heavily-infected fish. This is accompanied by sluggishness and a partial or complete loss of appetite. When an infected fish is viewed in a bright light at the proper angle, a white translucent covering or film can be seen extending over the body which in places reaches a considerable thickness, forming the white blotches previously mentioned. This film is composed of cells produced by hyperplasia of the epidermis. The scales become loosened and the skin may show a reddish tinge due to congestion of the blood vessels. This thickening of the epidermis, which is a protective reaction on the part of the host, actually benefits the trichodinid parasites, since they feed on the cells thus formed. Some of the smaller species, such as *T. myakkae* are too small to ingest epithelial cells and appear to feed largely on bacteria that may be present.

Fish are infected by direct transmission and there is no evidence that the parasites can spread by any other means. Richardson (1937) found that 12 hours after the introduction of an infected trout into a container with 2 clean fish, the latter were as heavily infected as the former. He also found that the length of time the parasite can live off the fish depends upon the temperature. When a fish dies the parasites escape slowly from the host and at room temperatures (22°-25°C.) may continue to leave the fish for 8 to 10 hours. At lower temperatures the process was greatly prolonged. At 11°C. live trichodinids were present on the dead host up to 72 hours and at 4.5° C. they survived for 140 hours after the death of the host.

CONTROL

Control of *Trichodina* is very easy. A treatment with a 3 percent salt solution or with a 1 to 500 solution of acetic acid is ordinarily sufficient to rid fish of this parasite. Treatment with a 1 to 4,000 solution of formalin is, of course, very effective, and is to be preferred where it is not advisable to handle fish or when other external parasites are present.

References: Mueller, 1932, 1937; Plehn, 1924, Richardson, 1937.

Ichthyophthirius

The protozoan, *Ichthyophthirius multifilis,* usually known as "ich," is common on pond fishes, but is rarely injurious to trout. This is due to the fact that the parasite develops slowly at low temperatures and is unable to complete its life cycle where there is a rapid flow of water. Consequently, it seldom becomes established at trout hatcheries; but in some instances, where conditions were somewhat unusual, it has caused serious losses among trout of all ages.

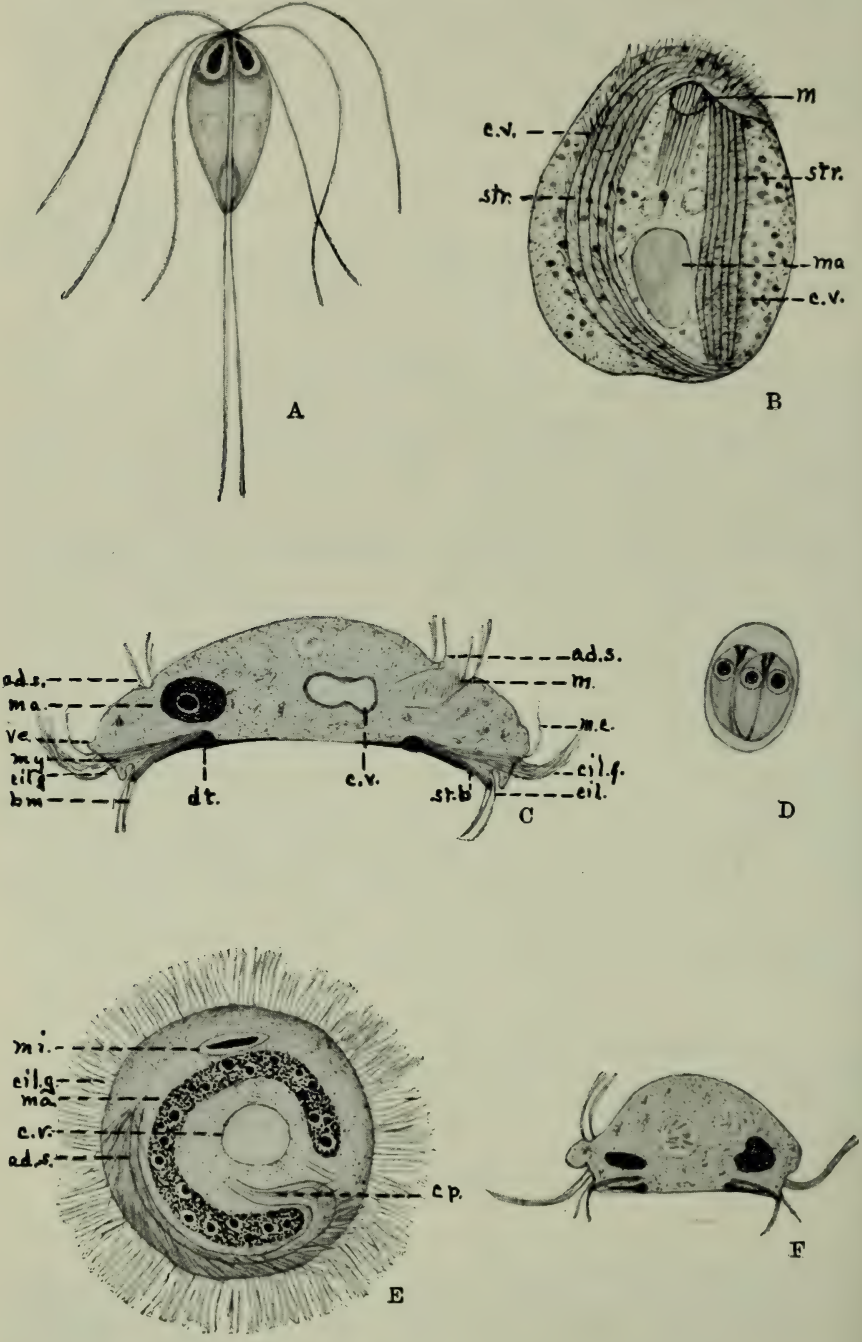

FIGURE 10.—For description, see opposite page.

SYMPTOMS

The most characteristic symptom of ichthyophthiriasis, the disease caused by this parasite, is the presence of small, greyish white swellings or elevations on the body and fins. These swellings are usually sharply defined, but when fish are heavily infected, they may be so close together as to merge into one another, thus forming irregular, light-colored patches. Similar lesions occur also on the gills, but are not so easily seen as those on the body.

In early stages of the disease, the infected fish usually rub against the sides or bottom of the pond in an effort to rid themselves of the parasites. As this is also a characteristic reaction of fish infected with *Gyrodactylus,* it should not be interpreted as a specific symptom of the disease. Infected trout also show a marked tendency to get into rapidly flowing water, and may leap into the air more than usual, apparently in distress. In late stages of the disease the fish become sluggish and lie around the edges of the pond where they can be easily captured.

DESCRIPTION AND LIFE HISTORY

The parasite can be identified easily by scraping material from the surface of the body and examining this in water under a low magnification. A fully grown specimen is exceptionally large for a protozoan, reaching a diameter of nearly 1 millimeter, and can be distinguished with the naked eye as a minute, rounded, white body slowly swimming about. Under the microscope the parasite appears spherical or oval in shape and covered with rows of fine, hair-like cilia by which the animal propels itself through the water. There is a small circular mouth opening at one end, while scattered throughout the body are a number of small contractile vacuoles and numerous opaque granulas. Near the center of the body is a large crescent-shaped nucleus (fig. 9, J).

This protozoan has a very interesting and complicated life history (fig. 11), a knowledge of which is essential in order to combat the infection intelligently.

Protozoan parasites of trout: A. Flagellate form of *Octomitus salmonis.* The deeply stained paired nuclei surrounded by a lighter area can be seen at the anterior end. Extending the length of the body is a pair of axostyles to which are attached 3 pairs of flagella at the anterior end and a fourth pair at the posterior end. x 1,950. B. Ventral view of *Chilodon* sp. from black bass. The mouth opening into the cytopharynx surrounded by rod-like structures can be seen near the anterior end. On each side of the mouth are several parallel lines or striations bearing cilia. The large macronucleus is located in the posterior half of the body. The micronucleus is not shown. There are 2 contractile vacuoles about one-third of the distance from each end. Drawn from unstained specimen killed in osmic vapor. x 1,000. C. Cross-section of *Trichodina* sp. from the bluegill sunfish. The adoral spiral, composed of 2 rows of cilia, can be seen above the mouth and at the opposite side of the adoral surface. On the lower side of the body is the adhesive disk composed of the denticulate ring, the striated band, and border membrane. Just above the striated band are the myonemes connecting the band with the ciliary girdle. x 1,340. D. Cyst of *Octomitus salmonis* containing 2 individuals surrounded by the transparent cyst wall. x 1,950. E. Adoral view of *Trichodina myakkae.* Surrounding the body are the membranelles of the ciliary girdle. The adoral spiral extends only about one-half the distance around the body and leads into the cytopharynx, located between the arms of the macronucleus. In the middle of the body is the contractile vacuole which opens to the exterior at one side of the mouth. x 1,340. F. Cross-section of *Trichodina myakkae.* The deeply stained macronucleus can be seen at each side of the body. At the margin of the body is the ciliary girdle with the velum and adoral spiral above. There are 2 food vacuoles in the endoplasm containing partially digested bacteria. x 1,340. Abbreviations: ad.s. adoral spiral; b.m. border membrane; cil. cilia; cil.g. ciliary girdle; c.v. contractile vacuole; dt. denticulate ring; m. mouth; ma. macronucleus; m.c. marginal cilia; mi. micronucleus; my. myoneme; str. striations; ve. velum.

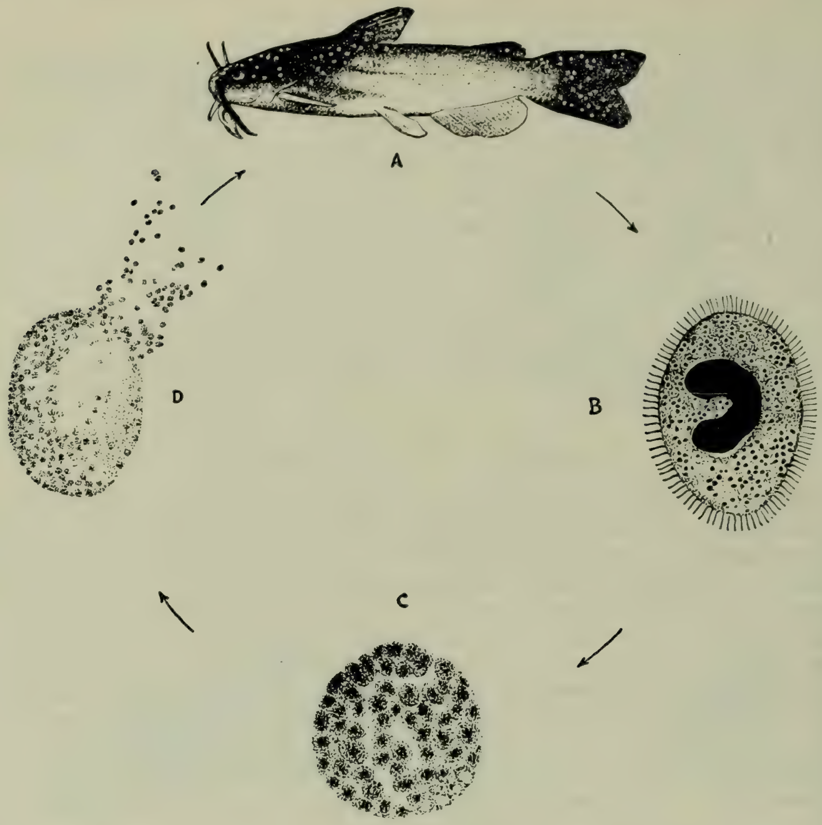

FIGURE 11.—Life cycle of the *Ichthyophthirius multifilis.* A. Adult parasite on catfish. B. Parasite after leaving fish as a free-swimming form and settling to the bottom. C. Division of adult into many smaller individuals after formation of cyst. D. Bursting of cyst, releasing hundreds of minute parasites, which in turn reinfect the fish.

The young parasite is very small and entirely different in appearance from the adult. It swims about actively in search of a host, and when it comes in contact with a fish, it bores into the epidermis, attaches itself by one end of the cone-shaped body and rotates rapidly so that it quickly displaces some of the epithelial cells. In this way the parasite gradually works its way into the deeper layers of the epidermis (fig. 9, I) destroying the cells in its path. Wolf (1938) finds that in trout, at least, the parasite eventually comes to rest between the epidermis and the corium. This is undoubtedly often the case in other fishes as well (fig. 9, H). As a result of the irritation caused by the boring of the parasite into the tissues, there is a rapid proliferation of epidermal cells; and in the gills, where there is little connective tissue, the parasite frequently appears to be surrounded entirely by the greatly thickened epithelium (fig. 9, J).

Once embedded in the skin or gills of the host the parasite begins to grow rapidly and soon appears to the naked eye as the little white spot or swelling previously mentioned. When full grown, the parasite leaves the fish and drops to the bottom, where it soon forms a cyst by secreting a thin membrane around itself. Within the cyst it multiplies rapidly by division, and eventually a large number of minute young are produced, which are invisible to the naked eye. When reproduction is completed, the cyst wall breaks open, releasing hundreds (in some instances thousands) of young, which immediately swim off in search of a new host.

CONTROL

Owing to the fact that during most of its life the parasite is surrounded by the living cells of the host where it cannot be reached by chemicals, *Ichthyophthirius* is more difficult to combat than most external parasites. When not embedded in the skin or gills, it is easily killed by various chemicals such as a 3 percent salt solution and exposure for 1 hour to a 1 to 4,000 solution of formalin. In using salt, the fish may be dipped into the solution until they show signs of distress or the salt may be added to the troughs in the usual manner. Since parasites embedded in the skin are not affected by the solution, it is necessary to repeat this treatment on several succesive days in order to kill them as they emerge. The length of time required to free the fish of parasites will depend on the temperature, for the lower the temperature, the longer the time required. If the fish are retained in the pond after treatment, it should be sterilized each time with quicklime or chlorine. Accordingly to MacLennan (1935) the encysted forms are not resistant to drying or to chemicals and can be easily destroyed. He finds, however, that the encysted stage may last as long as 5 days, and that for an additional 96 hours, the spores are capable of infecting fish. It thus appears that infection is possible for at least 8 days after the fish are removed; and probably a considerably longer time must elapse before it would be safe to use the pond unless it had been thoroughly dried out or disinfected.

Owing to the difficulty of killing the parasites by the external application of chemicals, a more practical method is to remove them as they leave the fish. This may be done by holding infected fish in swiftly running water which carries the parasites away before they have an opportunity to multiply and reinfect the fish. This method can be applied easily at any trout hatchery as it is necessary only to hold the fish in troughs or raceways through which a good current of water is flowing. There should be a complete circulation with no dead areas in which the parasites can lie until they complete encystment. Naturally, it will be necessary to hold the fish in running water for several days until all parasites on the fish have disappeared.

References: Butcher, 1940; MacLennan, 1935; Prytherch, 1924; Wolf, 1938a.

INTERNAL ANIMAL PARASITES

Parasitic Worms

Although many species of parasitic worms are known to occur in trout, they are, fortunately, very rarely so abundant in hatchery fish as to cause appreciable injury. This is in striking contrast to other types of parasites, which are almost invariably more abundant in trout at hatcheries than in those living under more natural conditions. The answer to this seeming paradox is, no doubt, to be found in the fact that almost all endoparasitic worms require at least two distinct hosts for the completion of the life cycle. The adult worm lives in an animal known as the primary host, whereas the larva is found in a very different animal known as the secondary or intermediate host. In some

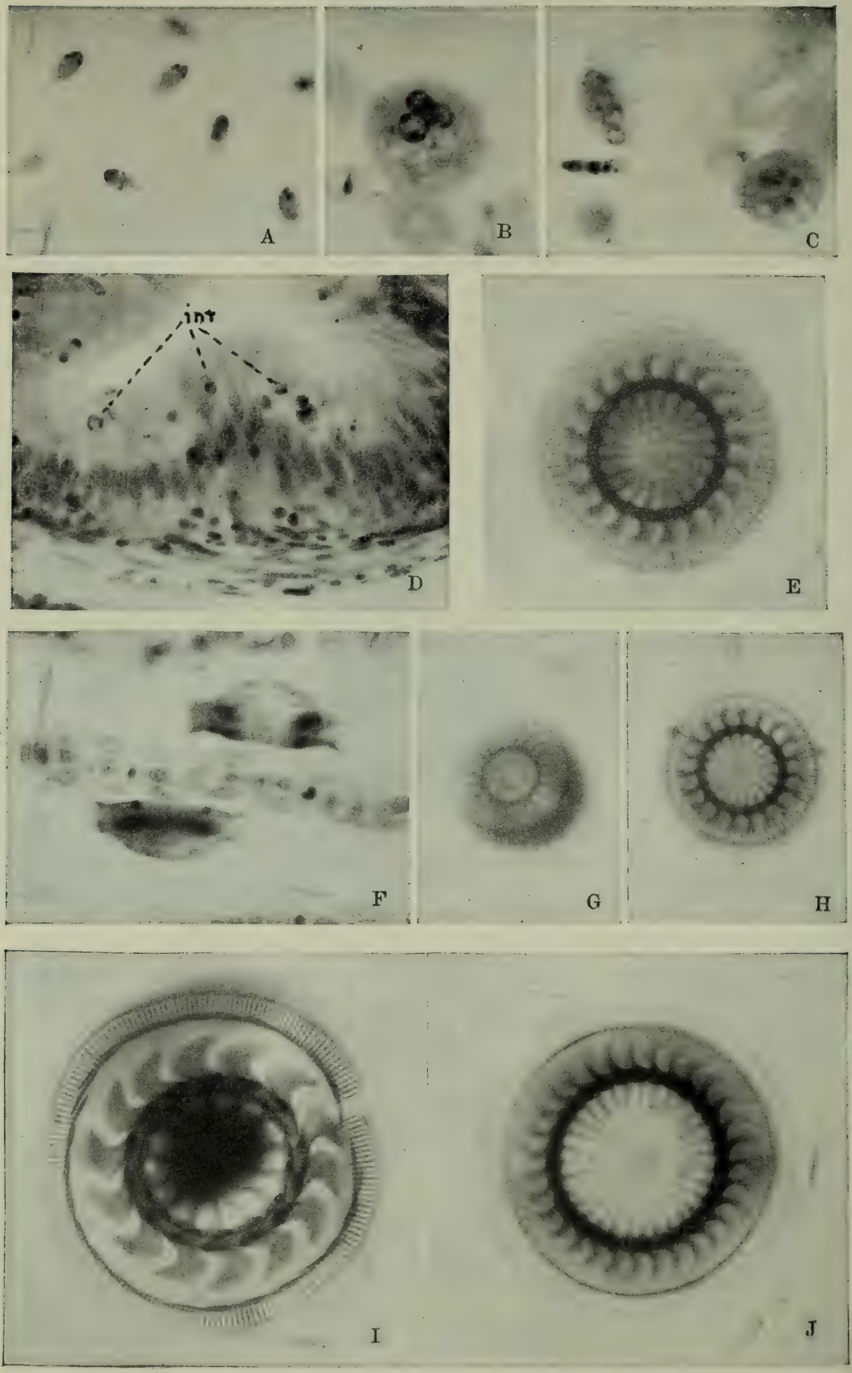

FIGURE 12.—For description, see opposite page.

cases the worm requires more than one secondary host for its complete development. The larvae can develop only to a certain stage in the secondary host, but should this animal be eaten by the primary host, they are then able to complete their development in the latter.

Trout may serve either as a primary or as a secondary host, but never as both for the same species of worm. Worms for which trout form the primary host usually in the larval stage inhabit some crustacean, whereas those worms that utilize trout as the secondary host usually occur in the adult stage in fish-eating birds. This being the case, it is easy to understand that there is little opportunity for these parasites to complete their life cycle in hatchery fish that, for the most part, are fed on artificial foods and protected from predacious enemies.

All types of parasitic worms occur in trout (Richardson 1936, 1941), including flukes (Trematoda), tapeworms (Cestoda), roundworms or threadworms (Nematoda), and spiny-headed worms (Acanthocephala). The flukes are so small that they are seldom noticed, although they may occur occasionally in the intestine. A larval fluke (one of the Strigeidae) may form cysts in the skin. Since these cysts are surrounded with pigment, they appear as minute black spots, which, when abundant, are rather conspicuous. Similar cysts are common in the skin of yellow perch, minnows, and other pond fishes.

The larvae of several species of strigeids occur in the eyes of fish and one has recently caused heavy losses among trout of various sizes at the New Jersey State Hatchery at Hackettstown, (Palmer, 1939; Ferguson and Hayford, 1941). Ferguson and Hayford have provisionally identified this parasite as *Diplostomum flexicaudum,* described by Van Haitsma from the eyes of the common sucker.

The last larval stage of the parasite (metacercaria) occurred only in the lens of the eye and when abundant, caused it to become white and opaque, which resulted in partial or total blindness. In extreme cases the lens became soft and eventually disintegrated. The fish died from starvation caused by blindness. Rainbow, brown, and brook trout were infected, but the flukes were most abundant in rainbow trout, which suffered a heavy mortality. The

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Photomicrographs of protozoan parasites: A. *Octomitus salmonis* photographed from a smear made from the intestinal contents. The paired nuclei with axostyles between can be easily distinguished. The flagella are not visible. x 680. B. and C. *Schizamoeba salmonis* photographed from sections of a trout stomach. B shows a large ameboid form with 3 nuclei. The rounded form at the right in C is an early stage in cyst formation. An ameboid form with 4 nuclei can be seen at upper left. x 680. D. Cross-section of a portion of one of the pyloric caeca of trout containing intracellular stages (int.) of *O. salmonis* in the epithelium. x 330. E. Adhesive disk of an adult *Trichodina* sp. from the bluegill sunfish. The most conspicuous structure is the denticulate ring with the broad hooks on the outer side and the slender, pointed rays projecting inward. Outside of the hooks is the striated band composed of radiating lines. This in turn is surrounded by the delicate border membrane which is also striated. x 680. F. Sections of *Trichodina* sp. attached to gill lamella of sunfish. The deeply stained macronuclei can be seen above the denticulate ring. x 680. G. Adhesive disk of *T. myakkae*. Note absence of rays on inner side of denticulate ring. x 680. H. Adhesive disk of a juvenile *Trichodina* sp. from sunfish. The faint lines in the striated band alternating with those much better defined are the new bars which are just beginning to form. Compare with fig. E. x 680. I. Adhesive disk of a juvenile *Trichodina* sp. from black bass which has just been formed by binary fission. The striated band and denticulate ring have not quite closed. The new denticulate ring is represented by a series of overlapping plates in the striated band. Each plate will develop into a denticle of the new ring. The inner part of the bars in the striated band will be resorbed along with the old denticulate ring. The dark shadow within the denticulate ring is the macronucleus which lies at a lower level. x 680. J. Adhesive disk of *Trichodina truttae*. Photographed from a specimen preserved in formalin. x 340.

eyes of suckers and blackhead minnows also contained large numbers of flukes, though those of the bluegill sunfish were less heavily infected.

Like all strigeids, this worm has a complex life history. The adult worms are found in the intestines of several species of gulls. The eggs pass from the birds with the feces and hatch in water into small, free-swimming larvae (miracidia). These larvae must make their way into snails of the genus *Lymnaea* within a few hours, otherwise they die. Once in the snail they undergo a complicated development, multiply, and form a second free-swimming stage (cercariae) in which they penetrate the tissues of a fish and eventually come to rest in the lens. Cercariae first begin to emerge from the snail about 6 weeks after entrance of the miracidia. Thousands of cercariae may leave the snail in a day and this process may continue for several weeks. Gulls become infected by eating parasitized fish.

The most effective method of controlling eye flukes, as well as other species of trematodes with a similar life history, is to destroy the snail hosts. This can be done by the use of chemicals such as chlorine or copper sulphate (p. 27).

Ward and Mueller (1926) have described a form of "popeye" in black-spotted trout at one of the Oregon State hatcheries, caused by heavy infestation with the larvae of a trematode. The larvae formed minute cysts in various parts of the body and were so abundant as to cause heavy mortality. The protrusion of the eyes was apparently due to the presence of cysts in the optic nerve, as only those fish in which cysts were found embedded in one or both of these nerves showed the popeye condition. The enormous number of cysts found in this instance can probably be accounted for by the presence of snails in the nursery ponds. From our knowledge of the life history of closely related worms it seems very probable that this parasite requires two secondary hosts. The first is a mollusk (probably a snail) in which the parasite multiplies rapidly, after which it becomes encysted in fish, which form the second intermediate host.

A number of tapeworms have been reported from trout, probably one of the best known being the species described years ago by Leidy under the name *Dibothrium cordiceps*. The larvae of this species are very common in the muscles and body cavity of trout in Yellowstone Lake and for that reason have attracted considerable attention. The adult tapeworm is found in the white pelican, which is common there. Fasten (1922) has found a similar worm very abundant in trout from certain lakes in Washington.

Another tapeworm, *Abothrium crassum*, which is common in salmon in both this country and Europe, has been found in considerable numbers at one of the Vermont State hatcheries. Only the adult worm lives in trout and salmon, in the pyloric region of the intestine.

McKernan (1940) succeeded in ridding trout of tapeworms in the intestine by the use of kamala. The fish under experiment were badly infected with an undescribed species of *Proteocephalus*, as many as 5 worms, 50 to 90 millimeters long, being found in the intestine of 3-inch trout. Kamala was thoroughly mixed with the food in the proportion of 1½ to 2 percent by weight, and after one week the fish were found to be entirely free from the worms.

Roundworms, or nematodes, are comparatively rare in trout. One species, *Cystidicola stigmatura*, has been reported frequently in salmonid fishes from the Great Lakes, and has also been found in brook trout from several streams in Pennsylvania. The small, white, thread-like adult worms, about 1 to 1½ inches long, live in the air bladder and are sometimes present in large numbers. The larvae occur in the freshwater shrimp (*Gammarus*).

The spiny-headed worms are characterized by a retractile proboscis, armed with numbers of recurved hooks, which is embedded in the intestinal wall, this sometimes resulting in infection followed by severe inflammation. Like the tapeworms, the spiny-headed worms have no digestive tract, but unlike the former, they have a body that is small and unsegmented. One of these worms is sometimes rather abundant in European trout and is reported to have caused considerable mortality. The writer has seen specimens of brook trout from Newfoundland that were so badly infested with spiny-headed worms that they must have suffered considerable injury.

References: Fasten, 1922; Ferguson and Hayford, 1941; Linton, 1891; McKernan, 1940; Palmer, 1939; Ward and Mueller, 1926.

Protozoa

Octomitus salmonis

A small protozoan parasite known as *Octomitus salmonis* occurs in the intestine of trout and salmon. This parasite has received considerable attention during recent years because it has proved to be the cause of serious mortality among fingerling trout in our hatcheries.

This parasite is widely distributed throughout the country, having been reported from trout hatcheries in many different localities, and it is probable that there are very few hatcheries at which it does not occur. It has not been found in wild fish except under circumstances which indicate that the infection was probably derived from hatchery fish. There is, however, no reason to doubt that the parasite does occur naturally in wild trout, but under such conditions, it is probably seldom sufficiently abundant to cause noticeable injury. It is only when the fish are crowded together in the hatchery that *Octomitus* becomes a serious problem.

All species of trout and salmon propagated artificially may become infected with *Octomitus salmonis*. In most cases it is more injurious to brook trout than to either rainbow or brown trout, although at a few hatcheries the rainbow appears to be more susceptible than the brook trout. It is notable that this is true only at hatcheries where rainbow trout is the principal species reared, and it is not improbable that under such conditions a physiological strain of the parasite has been developed that is more virulent in rainbow than in brook trout.

SYMPTOMS

Octomitiasis is not characterized by well-defined symptoms by means of which it can be readily distinguished from other ailments of trout. There are no external lesions, and the most common indication of the presence of the disease is the appearance of very emaciated fish commonly referred to as "pinheads." Many of the pinheads may improve after a time and eventually resume their normal rate of growth, but others gradually grow weaker and weaker until death supervenes.

More rarely the disease occurs in an acute form accompanied by heavy mortality. In such cases the fish may exhibit a whirling or corkscrew motion in the water or may lie on the bottom of the trough and bend the body from side to side with quick, spasmodic movements. Too much emphasis should not be placed on the significance of such movements, however, since they undoubtedly accompany other intestinal disorders.

Often a prominent feature of the disease is the spotty nature of the outbreak. Instead of appearing simultaneously in all the troughs containing a certain lot of fish, the disease may first break out in one or in several troughs that are not connected in any way. It frequently happens that all the troughs containing fish from the same lot of eggs will eventually show the disease, although by the time it appears in the last of the troughs it may already have run its course in the troughs first affected.

The simplest and most reliable method of diagnosing the disease consists of a microscopical examination of the contents of the anterior end of the intestine. This material should be mounted on a slide in a drop of water, in which the parasites will remain alive and active for 10 to 15 minutes. As no other parasites that could be confused with *Octomitus* are likely to be encountered, an examination with the low power of a compound microscope is usually sufficient. At this magnification the parasites can easily be seen as colorless, minute, pear-shaped organisms darting rapidly about in every direction. In some instances the parasites do not occur in the cavity of the intestine, but only in the intestinal lining. This condition, however, is usually found in only very young fingerlings.

DESCRIPTION AND LIFE HISTORY

The parastic protozoan that causes octomitiasis belongs to the group called Flagellata, the members of which are characterized by the possession of one or more long, whip-like locomotor organs known as flagella. In *Octomitus* there are 4 pairs of these flagella, 3 of which are attached to the broader anterior end of the body while the fourth pair arises from the posterior end. In life it is very difficult to distinguish the flagella, because they are transparent and usually in rapid motion.

The body of *Octomitus* is colorless and transparent, and in order to make out the details of its structure, it is necessary to kill and stain the organism (fig. 10, A). It is then found that there is a pair of chitinous rods, known as axostyles, extending throughout the length of the body, to which the flagella previously referred to are attached. On each side of the axostyles near the anterior end is an elongated nucleus, each nucleus being connected with the nearer axostyle.

In the flagellate stage the parasites reproduce by a process known as binary fission, during which the organisms become rounded and the various cell structures, with the exception of the flagella, divide into 2 equal parts. New flagella are quickly developed, so that the daughter flagellates are identical with the mother in every respect but size. Since the process requires but a short time, it follows that under favorable conditions the flagellates may multiply very rapidly.

At certain times cysts are formed, which can live for a considerable period outside the host, and it is probably by this means that the parasites are ordinarily transmitted from fish to fish. The cysts (fig. 10, D), which are oval to spherical in shape, are formed by flagellates that become surrounded by a thin transparent membrane. Shortly after the membrane is formed the inclosed organism divides into 2, and in this condition the cysts pass out of the intestine in the feces. They can remain alive in the water for days, probably for weeks, and when accidentally swallowed by another fish, may set up a new infection. In this they are aided by the tough, resistant membrane, which enables the cysts to withstand conditions that would quickly kill the flagellated forms.

In addition to the flagellates in the intestinal cavity, there is another stage of the life cycle (fig. 12, D) that is found in the epithelial cells that line the intestine and pyloric caeca. This stage is very different from the flagellated stage previously described. It first appears as a small rounded cell, which increases rapidly in size and soon divides into a number of small cells similar to the original. These daughter cells in their turn invade other epithelial cells and repeat the cycle. Under certain conditions these intracellular stages may multiply so very rapidly that a large percentage of the epithelial cells become infected. After a time, some of the intracellular parasites develop into the flagellated form and then quickly emerge into the cavity of the intestine.

PATHOLOGY

The effects of the parasites on the host undoubtedly vary widely under different conditions, and there is still much to be learned in this regard. The evidence at hand is contradictory in some respects, but it is believed that much of this apparent discrepancy can be explained on the basis of the 2 cycles of development within the host.

It is undoubtedly true that fish may harbor large numbers of flagellates without exhibiting any noticeable ill effects. This, however, appears to be largely a matter of age and probably also of acquired immunity on the part of the host. Ordinarily, trout over 3 or 4 inches in length show little or no ill effects, even when the parasite is abundant in the intestine, while the younger fish, under the same conditions, may exhibit every evidence of malnutrition.

Among young fingerlings the effects of a severe infestation by the flagellates are, as a rule, decidedly marked. Such fish lose their appetite and become greatly emaciated, the large head and attenuated body suggesting the term "pinhead," by which they are commonly known among fish-culturists. They are usually weak and listless and in late stages of the disease may become too feeble to fight the current and thus, are liable to be swept against the screen, where they soon die.

This chronic form of octomitiasis is ordinarily most prevalent during the spring and early summer, when the fingerlings are from 2 to 3 inches long. Although the mortality is usually not very heavy at any time, the disease may persist for several weeks, so that the total loss may be as high as 50 or even 75 percent. Chronic octomitiasis is probably prevalent to a greater or lesser extent at most trout hatcheries where the fingerlings are held until summer or later, although the severity of the mortality appears to be dependent on a number of environmental factors, among which unsuitable food and overcrowding appear to be especially important.

Although the chronic wasting disease just described is undoubtedly the most common result of infection by *Octomitus,* there is another form of octomitiasis, previously referred to, which manifests itself as an acute infection accompanied by a high mortality. Such epidemics occur only sporadically and are normally not of regular recurrence year after year as is the chronic form of the disease. In the majority of cases acute octomitiasis occurs early in the season shortly after the fish begin to feed.

Acute octomitiasis is caused by a rapid multiplication of the intracellular stages of the parasite, the flagellated stages frequently being entirely absent. As a result, there is considerable injury to the intestinal lining, accompanied by more or less inflammation, which quickly causes the death of the fish.

While there are 2 distinct forms of the disease, it is nevertheless true that in most instances we have to deal with a combination of these. It is probable that even in the chronic wasting type of octomitiasis, these parasites in the intracellular stages may sometimes be an important factor, since they are invariably present. In fact, a comparison of dying fish with emaciated but fairly vigorous individuals in the same lot has shown that in most instances, parasites in the intracellular stages were more numerous in the former.

It should be emphasized that loss of appetite and emaciation is not invariably due to the presence of *Octomitus,* and there is an all too common tendency to hold this parasite responsible for any sickness or mortality that cannot be easily explained. The presence of *Octomitus* in the intestine can be readily determined by a microscopical examination and, with the exception of small fingerlings, failure to find the flagellates in numbers may be taken as conclusive evidence that some other agent is responsible for whatever diseased condition may be present.

M'Gonigle (1940) was unable to find any evidence that in the hatcheries of the Maritime Provinces of Canada *Octomitus* was concerned in the heavy mortalities which frequently occurred among fingerling trout. He concluded that the mortality was due to acute catarrhal enteritis (see p. 87) which had no connection with *Octomitus.* The writer is in full agreement with M'Gonigle's contention that losses among small fingerlings have often been incorrectlly attributed to infection with *Octomitus,* but he is unable to follow this investigator in his further conclusion that octomitiasis is always a relatively unimportant factor in the mortalities of fingerlings. The evidence of the injurious effects of *Octomitus* is too conclusive to be thus lightly brushed aside.

CONTROL MEASURES

Because *Octomitus salmonis* is so widely distributed and may occur in fish of all ages, it appears impracticable to eliminate the parasite from a hatchery. In fact, there is no doubt that many fish harbor small numbers of the parasite and are consequently carriers of the disease.

Since Tunison and McCay (1933) reported that they had been successful in destroying the flagellate stage in the intestine by the addition of 0.2 percent calomel (mercurous chloride) to the food, this treatment has come into general use throughout the country. Tunison and McCay found that 0.5 percent carbon tetrachloride and beta napthol were also effective in ridding the fish of the parasites, but these chemicals have never come into general use.

In order to eliminate the flagellate stage, it is frequently necessary to administer calomel for several days in succession. There is evidence that under such circumstances calomel has a definitely toxic effect, and results in increased mortality. Smith and Quistorff (1940) have published results of experiments which indicate that the continued use of calomel in the diet over a long period is not harmful and may even be beneficial. It should be pointed out, however, that these investigators were dealing with perfectly healthy fish and that their experiments were confined to fingerling salmon. Consequently, their results do not necessarily prove that previous views regarding the toxicity of calomel were erroneous.

In view of the shortcomings of the calomel treatment, the experiments of Fish and McKernan (1940) and Nelson (1941) are of special importance. These experiments indicate that in carbarsone, we have a much more effective treatment for *Octomitus* than in calomel. Carbarsone was thoroughly mixed with the food in the same proportions as calomel (0.2 percent) and in every instance all flagellated forms of *Octomitus* disappeared within 4 days. Furthermore, there was no evidence of a toxic effect on the fish, even when the treatment was continued for 7 days. Carbarsone is the trade name for para-carbamino phenyl-arsonic acid and has been used with marked success in the treatment of intestinal amebiasis. It is a white crystalline odorless solid that is stable and practically insoluble in water. It is more expensive than calomel (about $3.00 per ounce), but this is counter-balanced by its greater efficiency and its freedom from toxic action.

As might be expected, none of these treatments is effective against the parasites during their intracellular stages, which appear to be uninjured. However, the elimination of the flagellates may indirectly affect the parasites in the intracellular stage through improvement in the general physical condition of the fish.

All available evidence points to the conclusion that if the fry and fingerlings can be kept in an otherwise healthy and vigorous condition, there is comparatively little danger of heavy losses from this disease; but if the vitality of the fish is lowered or they are subjected, even for a short period, to unfavorable conditions, there is great danger of a rapid increase in the abundance of the parasites, with correspondingly detrimental effect on the host.

There are many factors which may directly or indirectly cause an outbreak of octomitiasis. Among those that are most conducive to the development of *Octomitus* are overcrowding, unsuitable water supply, especially a deficiency of dissolved oxygen and improper food. Owing to the inherent defects of artificial propagation it is almost impossible entirely to avoid the unfavorable effects of these factors, but certainly in most instances much can be done to improve conditions.

It is a natural tendency to attempt to increase the output by overloading the equipment. In some cases this may succeed for a time, but it is likely sooner or later to result in disaster. The evil effects of overcrowding are, no doubt, in part due to an insufficient supply of dissolved oxygen, and this, of course, is especially noticeable when the water is not properly aerated before entering the troughs or raceways. Often the water from springs is deficient in this gas, and it should always be made to flow over an efficient aerating device to obviate any danger from this source.

A promising method of control, which has received comparatively little attention as yet, is the production of immune races of trout. There is considerable evidence that this is entirely feasible, but it will, of course, require rigid selection for several generations before conclusive results can be obtained. As a matter of fact, owing to the prevalence of octomitiasis, there has necessarily been more or less involuntary selection in this respect at many hatcheries which rear their own brood stock. This may be a partial explanation of the well-known fact that fingerlings from hatchery eggs usually grow faster and suffer smaller losses than those hatched from eggs obtained from wild fish.

References: Davis, 1924, 1925; Fish and McKernan, 1940; Moore, 1923, 1924; Nelson, 1941.

Schizamoeba salmonis

This is one of the most common parasites of hatchery trout, but there is no evidence that it is ever seriously harmful to the host. It is usually most abundant in healthy, vigorous fish and is ordinarily not common in those that are not in good condition. This is probably due primarily to the fact that the parasite rarely occurs in numbers in fish that have been without food for any length of time.

The parasitic ameba, *Schizamoeba salmonis,* lives in the stomach and intestine of all species of trout and salmon, but, like *Octomitus salmonis,* it has thus far been found only in hatchery fish or fish that might readily have become infected from hatchery fish. The amebae (figs. 12, B and 12, C) occur in the stomach as small, colorless organisms, more or less irregular in shape. The transparent protoplasm has a finely granulated structure containing one or more vesicular bodies, the nuclei. The amebae are found in the mucus that covers the lining of the stomach and are often very abundant. This vegetative ameboid stage disintegrates quickly when removed from the stomach and for that reason is rarely seen without special search.

The parasite is most commonly found in the encysted stage, which is frequently very abundant in both the stomach and intestine. In the latter the cysts are usually in the core of gelatinous mucoid material that forms the major part of the intestinal contents. The cysts are spherical and vary greatly in size, the average diameter being about 20 to 25 microns. They are surrounded by a thin, transparent membrane and, in addition to a number of nuclei, usually contain numerous spherical refringent bodies composed of fat. The cysts gradually increase in size and after a time divide into 4 to 11 cells of approximately equal size. At this stage they have a remarkable resemblance to a segmenting egg, but, of course, this similarity is only superficial.

The cysts provide a means by which the parasite may be transmitted from one fish to another. Protected by the surrounding membrane, they pass out of the intestine in the feces and may live for some time in water. If eventually taken into the stomach of another trout, the life cycle is repeated.

As previously pointed out, this parasite has not been observed appreciably to injure the host although when excessively abundant, it would seem that it must have some deleterious effect, even if this is limited to the consumption of food that would otherwise be utilized by the host.

This ameba is much more common in fingerlings than in older fish, although in several instances the writer has found it abundant in adult trout. It is probable that most hatchery fish harbor a few of these parasites, which would explain the ease with which the fingerlings become infected.

Reference: Davis, 1924.

Myxosporidia

The Myxosporidia are typically fish parasites all but a few species, which occur in amphibians and reptiles, being found only in fishes. They may live in the tissues of various parts of the body, but are especially common on the gills where they usually form small, white cysts. Many myxosporidians live in cavities of the body, being found in the gall bladder, kidney tubules, and urinary bladder. They all form great numbers of small, resistant spores by means of which they spread from one fish to another.

Trout undoubtedly are hosts to a number of myxosporidians, but so far they have received little attention. *Chloromyxum truttae* has been found by the writer in the gall bladder of brook trout in Vermont. The parasite occurred in both wild and hatchery fish and, while sometimes abundant, caused no appreciable injury. Myxosporidians have also been found in the kidney tubules of trout in widely-separated localities. In most cases they were members of the genus *Myxidium*, although other genera were represented. Figure 13, F, is a section of the kidney tubule of a wild brook trout from a stream near Staunton, Va. Although the parasites were abundant in certain parts of the kidney, there was little change in the appearance of the tubules. Recently, several species of Myxosporidia have been described by Fantham, Porter, and Richardson from wild brook trout in Canada.

Although in most cases myxosporidian parasites apparently cause little injury, there is always the possibility that, like many other parasites, they may at times become exceptionally abundant with serious results to the host. Some species, however, may be injurious, even in small numbers. During the summer of 1940 a species of *Myxidium* was found by the writer in the kidneys of fingerling cutthroat trout *(Salmo clarkii)* at an Oregon hatchery. The fish were showing a heavy mortality at the time, but since they were also suffering from gill disease and *Octomitus*, it is uncertain to what extent, if any, the kidney parasites were concerned in the mortality. A myxosporidian infection of the kidneys of carp is believed by Plehn (1924) to be involved in a dropsical condition of these fish, and the writer has found Myxosporidia in the kidney of fingerling salmon that showed similar symptoms.

Coccidia in Trout

A species of coccidia has been found in wild brook trout from Furnace Brook near Rutland, Vt., but has not been reported in trout from other localities nor has it been found in hatchery fish. In some instances, the fish showed a heavy infection (fig. 13, E) which resulted in extensive destruction of tissue invaded by the parasite.

These parasites occur in the epithelium of the pyloric caeca and to a lesser extent in the intestinal epithelium in the neighborhood of the caeca. Parasites in various stages of development are usually present in the epithelium, and those in stages immediately preceding sporulation are frequently found in the lumen of the intestine. Four spores are formed in each individual (zygote), each spore containing 2 sporozoites. This would place the organism in the genus *Eimeria*. It is probably an undescribed species, but has not been studied sufficiently to justify a definite conclusion.

Under favorable conditions coccidia may become very abundant and cause serious injury to the host. Coccidiosis in poultry is a fatal disease, but there is at present no evidence that coccidiosis in trout is particularly injurious. It is possible, however, that if once established at a hatchery, this parasite might cause serious trouble, since it multiplies rapidly and requires no intermediate host.

BACTERIAL DISEASES

Furunculosis

Furunculosis derives its name from the apparent similarity of the most characteristic lesions to human boils and furuncles. This resemblance is only superficial, however, since the structure of the furunculosis lesion is very different from that of a boil. Furthermore, these boil-like lesions are frequently absent and it is then necessary to rely on other criteria for diagnosis.

The disease affects chiefly the various species of salmonid fishes although a large number of fresh-water and marine fishes have been infected experimentally. It is probable, however, that few of these fishes would contract the disease in nature and it apparently occurs in epidemic form only among the Salmonidae. Of the trouts, the brown and brook trouts are particularly susceptible. The cutthroat trout is less susceptible than the preceding species while the rainbow trout is often considered immune. This is not strictly true, however, since the rainbow trout may contract the disease if continually exposed to sources of infection, or if suffering from injuries or lowered vitality. The results of experiments in Great Britain under the direction of the Furunculosis Committee (1933) agree with the writer's experience that the rainbow trout rarely contracts the disease. The brown trout was

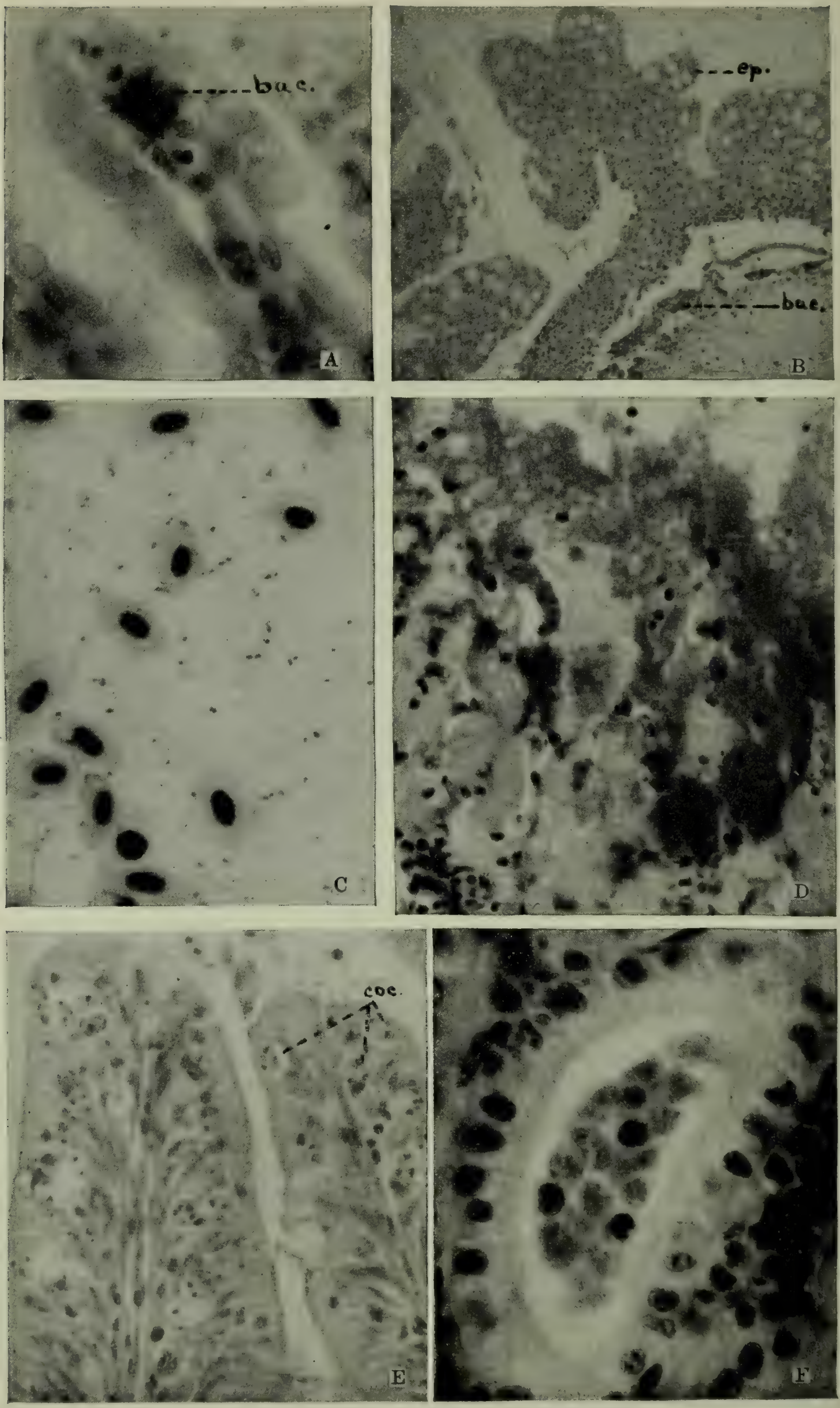

FIGURE 13.—For description, see opposite page.

found to be the most susceptible, while the brook trout appeared to be intermediate between that and the rainbow trout.

There is conclusive evidence that individuals of the same species exhibit great variation in susceptibility. Some resist infection entirely, while others readily contract the disease. As previously pointed out, evidence has recently been obtained which shows that this difference in susceptibility is largely a matter of heredity.

The investigations of the Furunculosis Committee indicate also that susceptibility in trout increases with age, young trout under 2 years being less susceptible than 3-year and older fish. This has not been the experience in this country, where fingerlings and yearlings frequently suffer very heavy losses. Among mature trout the disease is usually rare except during and shortly after the spawning season, when the fish are particularly susceptible to infection. In fact, it is at this time that the heaviest mortality ordinarily occurs.

Furunculosis was originally thought to be confined to hatcheries and fish farms, but a number of epidemics have been reported in wild fish during recent years, especially salmon in streams of Great Britain. In this country serious outbreaks of the disease have been confined to trout in hatcheries and rearing ponds. However, Duff (1932) reported the disease in Elk River at Fernie, British Columbia, where it caused serious losses among the Rocky Mountain whitefish (*Prosopium williamsoni*) and the Dolly Varden trout (*Salvelinus malma*). An occasional cutthroat trout (*Salmo clarkii*) was also affected. The disease occurred also in hybrid salmon (*Oncorhynchus*) in a rearing pond at Cultus Lake, British Columbia.

SYMPTOMS AND PATHOLOGY

The symptoms of the disease are usually well marked. The most characteristic one is the presence of open sores on the body. These ordinarily develop in the dorsal muscles, although they may occur on other parts of the body. Sometimes the lesions have a marked tendency to develop at or near the base of the dorsal or pelvic fins, hence, furunculosis has in some cases been confused with the disease known as fin rot, which is caused by an entirely different organism.

Photomicrographs of bacterial and protozoan parasites of trout: A. Section of gill lamella from trout with furunculosis. A large clump of bacteria (bac.) can be seen in a capillary near the edge of the lamella. The presence of the bacteria has resulted in considerable distension of the capillary. x 680. B. Section through small lesion of ulcer disease. The epithelium (ep.) is greatly thickened to form the epithelial tufts which are characteristic of the disease. Masses of bacteria (bac.) can be seen in the dermis beneath the epithelium. x 85. C. Blood smear from infected fish showing bacteria abundant in the blood plasma. The large oval cells with deeply stained nuclei are crythrocytes or red corpuscles. x 680. D. Section through furunculosis lesion in body muscle of trout. Large masses of bacteria can be seen among the more lightly stained muscle fibers which are in various stages of disintegration. In the upper part of the figure the muscle fibers have been entirely destroyed and only the nuclei (stained black) are left. In the lower left-hand corner is a cross-section of a capillary gorged with blood. x .340. E. Section through the epithelial lining of a pyloric caecum of brook trout infected with coccidia. The epithelium is filled with intracellular stages of the parasite (coc.) with consequent destruction of the epithelial cells. x 340. F. Section of kidney tubule of brook trout infected with Myxosporidia; probably a species of Leptotheca. The lumen of the tubule is filled with small trophozoites of the parasite. Several trophozoites contain spores which are deeply stained. x 680.

The disease is essentially a generalized septicemia, the bacteria being carried to all parts of the body in the blood stream. As the bacteria thus pass through the capillaries, they may collect here and there in small clumps which multiply rapidly, destroying the wall of the blood vessel and spreading out into the surrounding tissues (fig. 13, D).

The lesions thus formed appear to the naked eye as minute red spots in the subcutaneous tissue or among the muscle fibers. They contain large numbers of the causative bacteria which multiply rapidly, causing disintegration of the blood vessels and other tissues in the immediate vicinity. As a result, a swelling is formed which is filled with a deep red pus-like material composed of bacteria, blood, and disintegrated muscle fibers. Sometimes soft, blister-like lesions filled almost entirely with blood are formed just beneath the skin. The lesions increase in size and may eventually break through the skin to form an open sore. In many cases, however, death occurs before this happens. Especially is this the case in fingerling trout, in which usually the only evidence of the lesion that can be seen from the exterior is an irregular, dark blotch just beneath the skin on one side of the body. This blotch ordinarily is situated between the dorsal and pelvic fins and in young trout is probably the most characteristic symptom of the disease.

There is frequently a marked congestion of the blood vessels in the abdominal cavity. The lining of the intestine may be inflamed and there may be a discharge of blood and mucus from the vent, especially after death. The spleen is commonly enlarged and has a bright cherry-red color. This is decidedly noticeable in fingerling trout and is a very convenient diagnostic character. If the spleen is crushed in a drop of water underneath the coverglass, white clumps of bacteria can usually be seen, even when there is no other indication of the disease.

Masses of bacteria can also be found in the liver where they develop in much the same manner as in the spleen, but cannot be easily made out without sectioning and staining. The kidneys are ordinarily badly diseased and eventually may be converted into a semi-liquid mass. The gills are congested and clumps of bacteria can be distinguished in the capillaries (fig. 13, A). In short, the causative bacteria may occur in practically all parts of the body, but show a predilection for the more vascular organs, where they can be found in early stages of the disease before the more characteristic symptoms appear.

According to Plehn, the disease may occur rarely in an entirely different form, in which the causative organism is found only in the cavity of the intestine, at least until a comparatively late stage of the disease. In such cases there are no external symptoms, and recent investigations indicate that in some instances the bacteria may live in the intestine for a considerable time without any apparent injurious effects on the fish.

DESCRIPTION AND LIFE HISTORY

The bacteria were first described by Emmerich and Weibel in 1894 as the cause of an epidemic among trout in Germany. These authors called the organism *Bacterium salmonicida.* Later, Marsh, who was evidently unaware of Emmerich and Weibel's work, described an organism that he had isolated from the blood of diseased trout from Northville, Mich., and which he named *Bacterium truttae.* There can be little doubt that the bacteria described by Emmerich and Weibel and by Marsh are identical, and accordingly the specific name *salmonicida* takes precedence over the latter name *truttae.*

The bacterium (fig. 13, C) is a short rod about 2 to 3 microns long, with rounded ends, but may show considerable variation in form, especially when grown in culture media. The most important characteristic of the organism, which makes it easy to distinguish from other bacteria when growing in culture media, is the formation of a pigment which stains the media transparent brown.

The bacteria can usually be found in the blood of infected fish, where they are present in large numbers, occurring both singly and in large clumps. They grow best at a comparatively low temperature, the optimum being probably about 10° to 15° C. (50° to 60° F.). They are unable to live for any length of time at 37° C. and for that reason cannot develop in a warm-blooded animal.

The manner in which the disease is transmitted has not been definitely determined, but it seems most probable that the bacteria gain entrance to the body through the walls of the digestive tract or through small wounds on the body or gills. The disease may be readily transmitted experimentally by introducing the bacteria directly into the blood or tissues. After having gained entrance to the blood stream, they multiply rapidly and are carried to all parts of the body. Some of the bacteria may become localized in the muscles, where they produce the small red foci previously mentioned. These foci may eventually form large ulcers filled with a red pus-like material containing immense numbers of bacteria. The failure of such ulcers to develop in small fish is probably due to the death of the fish before the bacteria have been able to attack the muscles to any great extent. The dark blotches on the sides of the body, so characteristic of the disease in fingerling trout, are caused by the infiltration of blood among the muscle fibers, accompanied by some disintegration of the tissues; but death supervenes before the breaking of the muscle fibers has become an important feature of the lesion.

Among the visceral organs, the liver, spleen, and kidneys appear to be especially liable to infection. Large masses of the bacteria can usually be found in these organs, and the tissues of the spleen and kidney may be broken down entirely.

CONTROL MEASURES

In considering methods of controlling this disease, it is well to bear in mind that furunculosis is essentially a blood disease, the bacteria developing in tissues and cavities of the body, where they cannot be reached by the external application of chemicals. Consequently, it is idle to attempt to cure the fish by the use of salt baths or disinfecting solutions. Probably a certain percentage of infected fish recover from the disease, but recovery rarely occurs in fish in which the disease is so far advanced as to produce noticeable lesions.

This being the case, control measures must be designed primarily to prevent the spread of the infection to healthy fish. This is by no means a simple matter, since it has been shown that apparently healthy fish may act as carriers, which greatly increases the difficulty of control. In some instances the disease has run its course and apparently died out, only at a later time suddenly to break out afresh. In such cases the bacteria may have been carried over in the intestines of apparently healthy fish or possibly in the mud and debris on the bottom of the pond, and later, should the fish become weakened in any way, the bacteria are again able to get the upper hand.

A method of immunizing trout against *Bacterium salmonicida* by administering a vaccine in the food has been developed by Duff (1942). The vaccine was prepared by adding chloroform to an actively-growing culture of the bacteria which were killed in a short time. The dead culture was then thoroughly mixed with the food and fed once daily for several weeks, after which the fish were exposed to live virulent cultures of *Bacterium salmonicida* in water. It was found that after not less than 64 feedings of vaccine, the mortality in vaccinated trout was approximately 25 percent as compared with a mortality of 75 percent in the untreated fish. It is evident that while the results of Duff's experiments are very encouraging, this method of immunizing fish has not yet been sufficiently perfected to justify its general use.

Until some practicable means of immunizing fish has been developed, the only logical method of control is to destroy all infected fish at once. These should be burned, if possible, but if this is not practicable, they should at least be covered with lime and buried in pits at a sufficient distance from the ponds to prevent contamination. Dead fish should never be allowed to lie in the ponds, as putrefaction does not appear to injure the bacteria, which, when the fish decompose, are set free in enormous numbers.

All ponds in which diseased fish have been held should be thoroughly sterilized before being used again. According to German authorities a 1 to 100,000 solution of potassium permanganate will kill the bacteria of furunculosis if allowed to remain in the pond for a considerable time. Undoubtedly, the most effective method of sterilizing ponds is by use of chlorine (Davis, 1938; Hagen, 1940; Wolf, 1940). A concentration of 3 p.p.m. is sufficient to kill the bacteria, but where much organic matter is present, it is advisable to use a stronger solution. A freshly prepared solution of water-slaked lime is also effective and may be preferable under some circumstances. Needless to say, whatever the chemical used, great care should be exercised to insure that the solution penetrates all cracks and crevices where bacteria may be concealed. If practicable, the pond should be exposed to the sun for several days after disinfection and allowed to dry out as much as possible. Of course, all implements that could possibly carry the bacteria should be disinfected at the same time.

Several investigators have found that pure water is deleterious to the bacteria (Williamson, 1928) and that they die out quickly in water of this type, while they may live for weeks in sewage and in water containing an appreciable amount of organic matter. (Plehn, 1924; Duff *et al,* 1940). Consequently, it has been held that pollution is a predisposing factor, but Williamson (1928) was unable to find any connection between pollution and the disease. There is conclusive evidence, however, that warm weather and low water favor its development. Possibly the true explanation may lie in the fact that pollution, high temperatures, and low water tend to lower the vitality of trout and salmon and thus make them more susceptible to infection.

Of course, every precaution should be taken to prevent the spread of the disease from one hatchery to another through shipments of infected fish. In fact, no such shipments should be allowed from hatcheries in which the disease is known to be present. Fortunately, there appears to be less danger of the spread of the disease by means of eggs. According to Blake (1931) any possibility of the transmission of the disease in this way can be prevented by treating the eggs for 20 to 30 minutes with a 1 to 2,000 solution of acriflavine. There is, however, danger that the bacteria may be carried on the packing material or egg cases, and these should be destroyed or thoroughly disinfected if there is any reason to believe that they may have been contaminated.

References: Blake, 1931; Duff and Stewart, 1933; Furunculosis Committee, 1930, 1933, 1935; Plehn, 1924; Williamson, 1928.

Ulcer Disease

Ulcer disease is common at many hatcheries in the Northeastern United States, where it has caused high mortalities. According to Wolf (1938) it is primarily an ailment of brook trout though lake and brown trout are also susceptible. Rainbow trout are very resistant, but not immune.

The disease was first described by Calkins (1899) who found it present in epidemic form at a hatchery on Long Island. This investigator believed the disease was caused by a protozoan, but it is now generally recognized that there is little evidence to support this conclusion. Owing to the similarity of the lesions to those found in furunculosis, the two diseases were considered identical until Fish (1934) called attention to the fact that ulcer disease differed from furunculosis in several important respects.

SYMPTOMS

As the name signifies, ulcer disease is characterized by the formation of open sores or ulcers on the surface of the body which closely resemble those of furunculosis. In its early stages the lesion appears to the naked eye as a small, whitish pimple which may be situated almost anywhere on the surface of the body or head. Under the lens, it is evident that it is formed by a papilla-like outgrowth of the epidermis which later becomes wrinkled and very irregular in shape, frequently dividing into branched finger-like projections. These may reach a length of several millimeters and the whole structure has been appropriately termed an epithelial tuft by Fish. Not infrequently, there is a red discoloration at the base of the epithelial tuft, due to congestion of the blood vessels in the dermis or corium.

In advanced stages of the disease the lesion may be one-half inch or more in diameter, grayish-white at the center, where the muscle is exposed and surrounded by a white margin of thickened epithelium underneath which is a distinct reddish area as in earlier stages. Ordinarily the lesions are approximately circular in outline, although they may be irregular or greatly elongated.

One of the characteristics of this disease is the frequency with which the jaws and roof of the mouth become infected. Lesions on the jaws develop rapidly and may result in the entire eating away of the bones. The fins, especially the dorsal and caudal fins, are also attacked and the fin rays as well as the soft tissue destroyed. Sometimes the lesions develop first on the outer edge and extend toward the base as in fin rot, but in other cases lesions may appear mid-way or at the base of the fin rays. The fin rays eventually fall out, leaving a notch in the fin which appears as though a piece had been torn out. Not infrequently, the fins may be entirely destroyed.

While, as previously mentioned, the ulcers are similar to furunculosis lesions, they can usually, with little difficulty, be distinguished from the latter. Ordinarily, a furunculosis lesion appears first as a blister or bladder-like swelling beneath the skin, which eventually breaks through to the surface. It is filled with a red, pus-like material composed chiefly of blood and necrotic tissue. A lesion of ulcer disease, on the other hand, develops from the surface inward and does not extend for any distance into the muscles.

The muscular tissue appears to be eaten away cleanly from the surface and there is little evidence of undermining and the irregular disintegration of the deeper muscles so characteristic of furunculosis. Furthermore, the contents of the lesions of ulcer disease are usually light in color and easily washed away, leaving the grayish-white muscular tissue fully exposed.

According to Fish, the lesions of ulcer disease do not normally become fungused during the life of the fish; while in furunculosis, infection of the lesions with *Saprolegnia* is a common occurrence. Wolf, however, found that this is not universally true and that fungus may occasionally develop on ulcered fish.

PATHOLOGY AND CAUSE OF DISEASE

A typical ulcer starts as a papilla-like outgrowth of the epidermis which later divides into irregular finger-like structures, the epithelial tuft. This breaks down at the center and forms a sore or lesion. Sections through an open lesion (fig. 13, B) show a great thickening of the epithelium around the margin. Underneath, there is a mass of bacteria located in the dermis. As the ulcer grows, the bacteria invade the dermis in an ever increasing circle and cause its complete destruction so that in the center, the body muscles are exposed. Only rarely can bacteria be distinguished in the open part of the lesion, and the body muscle is not invaded as in the case of furunculosis. It is evident that for the most part the bacteria are confined to the dermis, and as this is destroyed, they are washed out of the lesion.

The appearance and development of the ulcers suggest that they are due to an infection which enters through the epithelium, and the experiments of Wolf (1938) support this view. Whether the bacteria are capable of penetrating the normal epithelium or can gain entrance only where it has been injured is still unknown. That the latter occasionally happens is indicated by the fact that several lesions may develop in a straight line, as though infection had occurred along a scratch in the epithelium.

The superficial character of the lesions is the most striking difference between ulcer disease and furunculosis. Sections of the liver, kidney, and spleen fail to show any evidence of bacteria as in furunculosis. Furthermore, Fish (1934) was unable to culture any bacteria from the blood or internal organs of diseased fish, but did isolate a bacterium from ulcers which proved to be pathogenic when used to inoculate healthy trout. He was unable to prove, however, that it was the cause of ulcer disease.

Working in the author's laboratory, Mrs. E. C. Lazar has isolated a bacterium from fish with ulcer disease which on inoculation produced lesions indistinguishable from typical ulcers of a natural infection. This organism, however, has the same cultural characters as *Bacterium salmonicida,* and serological tests by Dr. D. C. B. Duff have confirmed the identification. Brook trout inoculated with this organism by a slight prick with a needle developed a typical epithelial tuft at the site of the inoculation. Similar inoculations with *B. salmonicida* cultures procured from Dr. Duff failed to produce such a lesion.

After having been run through several fish the culture isolated by Mrs. Lazar increased in virulence and on inoculation into healthy trout, produced lesions indistinguishable from those found in typical cases of furunculosis. When first isolated, only superficial lesions were produced by experimental inoculations and on autopsy, the kidney, liver, and spleen appeared normal. Later inoculations, however, produced deeper lesions more like those of furunculosis and bacteria were found in the kidney, liver, and spleen.

The problem is still under investigation and it is too early to arrive at a definite conclusion, but there is much evidence to support the view that ulcer disease may be caused by a less virulent strain of *Bacterium salmonicida*, the causative organism of furunculosis. It is significant, for instance, that while a typical ulcer has a very different structure from a typical furunculosis lesion, there are many border-line cases. Wolf (1938) found in several instances that trout with typical ulcers also showed lesions characteristic of furunculosis, which developed internally and did not open on the surface of the body. The writer also has seen fish which showed furunculosis-like lesions as well as typical ulcers.

In the previous edition of this publication the author called attention to the resemblance between ulcer disease and fin rot and expressed the opinion that both diseases might be caused by the same organism. This theory has not been supported by recent developments, but Wolf (1940) concluded from his experiments that the two diseases are identical and that the term fin rot should be abandoned, since it is properly applicable only to the type of fin infection found in ulcer disease. In the author's opinion, there is no question that infections by different organisms have been called fin rot (see p. 66), but it does not follow that the infections so designated were usually ulcer disease. On the contrary, the original description of fin rot (Davis, 1928) was based primarily on an infection at a hatchery which had no history of the occurrence of either ulcer disease or furunculosis.

CONTROL

Since ulcer disease is evidently contracted by infection through the epidermis, there is a possibility that it can be controlled by dipping the fish in a disinfectant such as copper sulphate. Experiments by Wolf, however, indicate that such treatments are of little value, and it is doubtful if the disease can be controlled by such means. Apparently, the only effective measures are to destroy all fish in infected lots and thoroughly sterilize all pools and utensils as recommended for furunculosis .

References: Fish, 1934; Wolf, 1938, 1940, and 1940a.

Peduncle Disease

A remarkable disease appeared during June and July 1941 among fingerling rainbow trout at the Leetown, (W. Va.) hatchery. While invariably fatal, only a small percentage of the fish became infected and consequently the mortality was comparatively light. The disease reappeared during the spring of 1945. So far the disease has not been reported from any other hatchery.

SYMPTOMS

The appearance of the sick fish is so characteristic that there is no possibility of confusing peduncle disease with any known ailment. The disease usually appeared first on the adipose fin which became white along its outer edge. This discoloration extended gradually toward the base until it covered the entire fin (fig. 14, A) and then began to spread over the caudal peduncle. Eventually the entire peduncle became a dirty white, but by that time the adipose fin had disappeared and the integument on the dorsal side of the peduncle had disintegrated, exposing the muscle beneath. Fish in late stages of the disease were swimming about with the caudal fin still attached to the

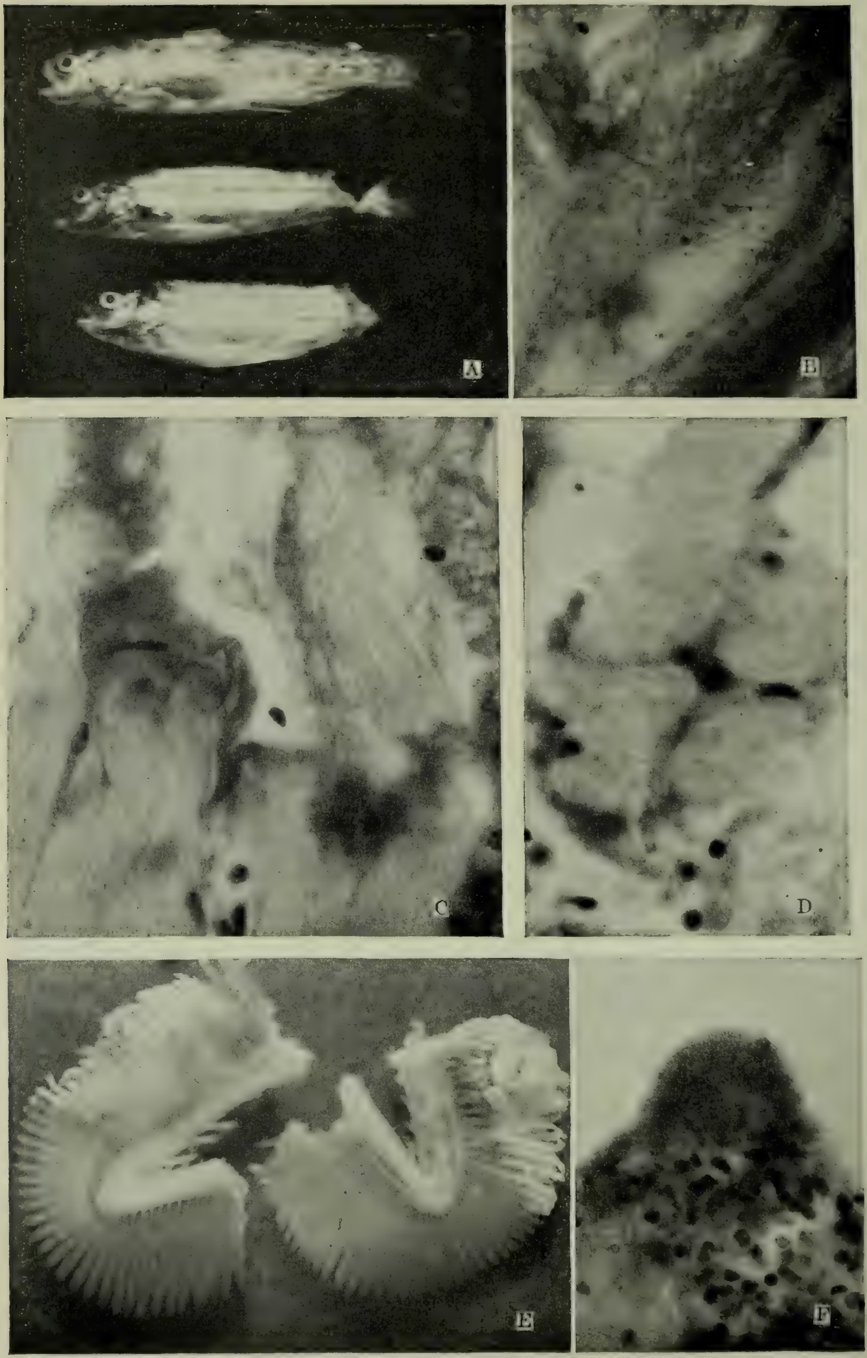

FIGURE 14.—For description, see opposite page.

vertebral column which was fully exposed. A few fish survived for a short time after the caudal fin had entirely disappeared.

PATHOLOGY AND CAUSE OF THE DISEASE

There is little doubt that the disease is caused by a bacterial infection which starts in the adipose fin and eventually spreads to the entire caudal peduncle and attached fins. In no case was the infection observed to extend anterior to the anal fin. This was probably due to the fact that the fish died before the infection could progress further. Material scraped from the surface of the caudal peduncle contained great numbers of a nearly pure culture of non-motile, slender, rod-shaped bacteria 3 to 5 microns long (fig. 14, B), which are believed to be the cause of the disease. Attempts to culture the bacteria have so far been unsuccessful.

The bacteria apparently first gain entrance through the epidermis of the adipose fin. Having penetrated the epidermis, they multiply rapidly in the dermis which is quickly destroyed, giving rise to the whitish discoloration so characteristic of the disease. Very few bacteria could be found among the epidermis cells although they were very numerous in the dermis. Following destruction of the integument, the bacteria invade the muscles through the connective tissue surrounding the muscle fibers. The advance of the bacteria among the muscle fibers is usually preceded by congestion of the blood vessels followed by local hemorrhage as the capillary walls are destroyed by bacterial action. This, in turn, is followed by destruction of the muscle fibers by bacteria which enter them from the end (figs. 14, C and 14, D). At first, the bacteria are arranged in parallel rows between the fibrils which soon disappear. As a result of this bacterial activity, the muscle fibers are broken down from the surface inward until the entire peduncle is destroyed. The lesions are always clean and clear-cut, indicating that all necrotic tissue is washed away as soon as formed.

CONTROL

It is evident that, as the tissues of the caudal peduncle are destroyed, the broken-down cells with great numbers of bacteria are continually being

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Photomicrographs of bacterial parasites of trout: A. Fingerling rainbow trout showing different stages of the peduncle disease. In the upper fish the adipose fin has become infected and has turned white as a result. The middle fish shows a considerably later stage of the disease. The muscles of the caudal peduncle have been destroyed exposing the vertebrae attached to the caudal fin which has also been partially destroyed. The last stage of the disease with loss of the caudal fin is shown by the third fish. B. Section through the mucus layer found at the advancing edge of a lesion on the caudal peduncle. The mucus is filled with the rod-shaped bacteria which cause the disease. C. Longitudinal section through infected muscle of the caudal peduncle. The section is in the region of the myocommata (the connective tissue partition separating the muscle segments) and shows the bacteria invading the ends of the muscle fibers. A few bacteria are already in the muscle fibers where they can be seen between the fibrils. x 680. D. Cross-section of infected muscle fibers in the caudal peduncle. The small dots scattered through the fibers are sections of bacteria lying between the muscle fibrils. Masses of bacteria can be seen in the connective tissue surrounding the muscle fibers. x 680. E. Gills of fingerling brook trout infected with *Cytophaga columnaris*. The lesion on the gill at the right is more advanced and is covered with a dirty white material composed of bacteria, remains of tissue cells and debris held together by a slimy substance secreted by the bacteria. x 3. F. Characteristic hay-cock like mass of bacteria on the surface of a lesion. This is the form assumed by the bacteria when transferred to a slide. In a few minutes they collect to form similar masses on the edge of scales or on bits of debris. x 680.

washed away. Consequently, water containing diseased fish is highly infective and spread of the disease can best be prevented by removing all fish which show any evidence of infection. As such fish will eventually die in any case, there is no reason for not getting rid of them at once. Of course, troughs, ponds and all utensils that have been contaminated should be thoroughly sterilized.

Overcrowding appears to be a predisposing factor, since the disease was most prevalent in troughs that were badly crowded.

Fin Rot

This disease, which is known also as tail rot, is prevalent at many hatcheries in widely separated localities. It is now evident that several diseases due to different causes have been confused under this term, and in the present state of our knowledge, it is not always possible to separate them. The following account applies to what is believed to be the typical form of fin rot, but until the causative organism has been isolated, it is impossible to distinguish it in all cases from other fin infections such as ulcer disease and furunculosis.

SYMPTOMS

As the name indicates, fin rot is characterized by disintegration of the fins which may eventually be entirely destroyed. Usually the infection appears first in the dorsal fin, but later may spread to the other fins. Occasionally the infection starts in the caudal fin which may be reduced to a mere stub.

Ordinarily the first noticeable indication of the disease is a more or less distinct white line along the outer margin of the fin. This white streak gradually moves toward the base of the fin, while at the same time the outer margin becomes badly frayed, owing to the disintegration of the tissue between the fin rays (fig. 15). This process continues until eventually the entire fin may be destroyed.

CAUSE AND PATHOLOGY

The causative organism is believed to be a rod-shaped bacterium, which can usually be found in large numbers in the infected fins. The writer has detected this organism in cases of fin rot from several different localities, and apparently it is the only organism that is uniformly present in the diseased tissues.

As previously indicated, the infection normally starts on the outer margin of the fin. As a result of the irritation caused by the growth of the bacteria, there is a rapid proliferation of the epithelial cells, so that the epithelium becomes greatly thickened. This thickened epithelium forms the white streak across the fin that is so characteristic of the early stages of the disease. Later the epithelium is destroyed, exposing the fin rays, which are also attacked by the bacteria and soon are frayed and broken. On the inner side of the infected area the bacteria are continually invading uninfected tissues, which in turn pass through the same sequence of events as those infected earlier.

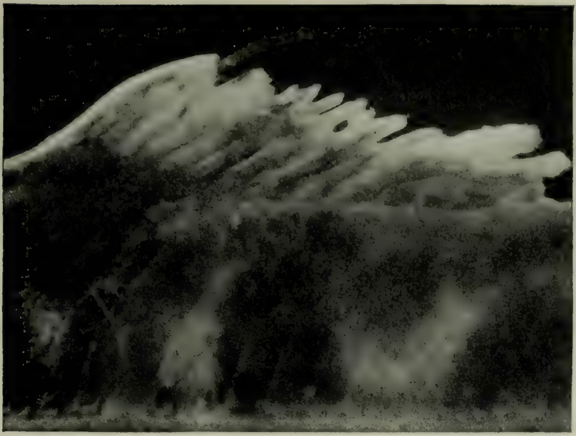

FIGURE 15.—Dorsal fin of fingerling brook trout infected with fin rot. Magnified 7 diameters.

The bacteria develop not only on the outer surface of the fins but invade also the tissues, chiefly the connective tissues. In their growth through the tissues the bacteria follow the lymph channels and frequently can be seen grouped in great masses around the fin rays. As the cartilages at the base of the fins are less resistant to bacterial action than the denser peripheral portions, they are sometimes destroyed first, and the fins may drop off instead of gradually disintegrating.

The dorsal fins of fingerling rainbow trout frequently show a light-colored, thickened area along the margin that has a superficial resemblance to an early stage of fin rot. Examination with a hand lens will show, however, that the margin of the fin has a smooth contour and lacks the ragged appearance and projecting fin rays so characteristic of fin rot. The thickened edge of the fin is composed of scar tissue, apparently the result of irritation, and there is no evidence that any infection is involved. It is most common in pools that are overcrowded.

CONTROL

In view of the method of infection outlined above, control measures obviously must be directed toward destroying the bacteria before they penetrate the tissues. This can be accomplished by dipping the fish for 1 or 2 minutes in a 1 to 2,000 solution of copper sulphate. This treatment has been found effective in early stages of the disease, but after the bacteria have gained entrance to the tissues, they are out of reach of chemical baths. Usually several treatments at intervals of 24 hours are required before the spread of the disease can be effectually checked. As it is impossible to cure fish in the advanced stages of the disease, all such fish should be destroyed before beginning the copper-sulphate treatment. If not removed, they form a continual source of infection, as great numbers of bacteria pass into the water from lesions on the fins and body. It is also essential that the troughs or ponds and all utensils used around the diseased fish be thoroughly disinfected.

The disease varies greatly in severity; in many instances only a small percentage of the fish die, while in other cases the mortality may be very high. In the milder form of the disease a large proportion of the infected fish may recover; the lesions heal before the fins are entirely destroyed, and the fins regenerate more or less completely.

Little information has been obtained regarding the factors that tend to bring on an outbreak of the disease. As in the case of so many other trout diseases, overcrowding is undoubtedly an important contributing factor. There is also evidence that sometimes *Gyrodactylus* may be involved. It is easy to understand how injury to the fins by this parasite might make them more susceptible to infection.

Gill Disease

The gills of fish are frequently infected by parasites of various kinds, especially protozoa and gyrodactylid worms. In trout, however, the term "gill disease" usually refers to specific infection characterized by certain effects on the gills. The disease is widely distributed over the United States, but is apparently more common at hatcheries in the eastern States than in the far west where another type of gill trouble is more prevalent. All species of trout and salmon are susceptible to this infection. The same or a similar disease has been observed in largemouth and smallmouth black bass, and in the black crappie.

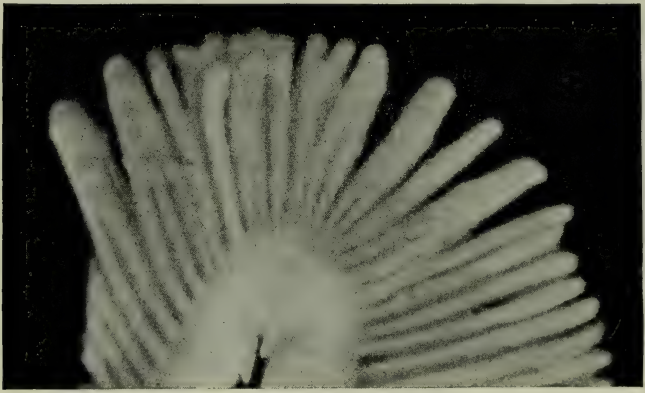

Figure 16.—Gills of fingerling trout affected with gill disease. Note that the gill filaments are enlarged at the ends, and in many instances adjoining filaments have become fused for some distance. Magnified 14 diameters.

SYMPTOMS

Unfortunately, the disease is not characterized by any well-defined symptoms other than the appearance of the gills and a general sluggishness and loss of appetite on the part of the fish. In fact, loss of appetite, while of course not specific for this disease, is probably, for the average fish culturist, the most reliable indication of its presence. Whenever fish of any lot suddenly stop taking food and lose their customary "pep" they should at once be examined for the possible presence of gill disease. In early stages of the disease, the gills are swollen and congested and consequently, appear a deeper red than usual. Later the gill filaments become more or less completely fused, while the tips become enlarged and distinctly lighter in color (figs. 16 and 17). Eventually the gills may become badly fungused, the fungus often spreading from the gills to the top and sides of the head. This

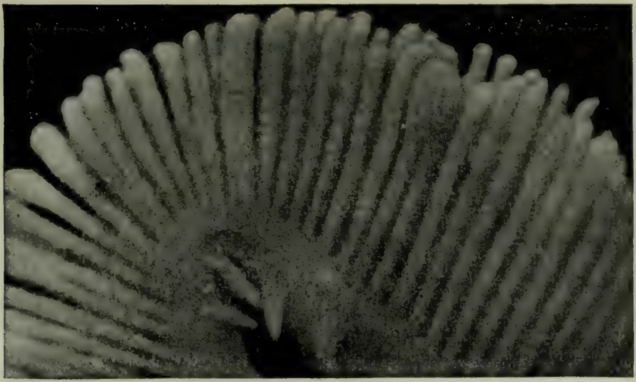

FIGURE 17.—Same as figure 16, but another view.

fungus is purely a secondary infection and, in the case of large fingerlings and yearlings, is almost invariably present before the fish die. Infected fry and small fingerlings, however, rarely show any trace of fungus, probably because the disease is so quickly fatal to small fish that fungus has no opportunity to develop.

Probably the most constant symptom that can be easily recognized is the greatly increased secretion of mucus by the gills. This is usually a prominent feature of the disease in fish of all ages and is particularly noticeable, as debris becomes entangled in the mucus and may so clog the gills as to interfere with respiration. It is well to bear in mind, however, that this excessive secretion of mucus by the gills is not distinctive, since it may be due to other causes as well as to gill disease.

The bacteria are most abundant on the outer third of the gill filaments, where, evidently as a result of the irritation set up by their presence, there is a rapid increase in the number of epithelial cells. This results in a marked thickening of the epithelium, especially at the ends of the filaments, which become greatly enlarged (fig. 18, D), accompanied by fusion of the lamellae into a continuous mass of tissue. Later, adjoining filaments may fuse, starting at the enlarged ends and extending toward their bases. In extreme cases all filaments on each side of the gill arch may be fused into a continuous mass. Sometimes the gills become necrotic, but as this condition is almost invariably accompanied by infection with fungus, it is probable that this organism is chiefly responsible. The fish usually succumb in a short time after the appearance of fungus.

CAUSE AND PATHOLOGY

This disease is caused by infection with bacteria that occur in the form of long, thread-like filaments which usually lie side by side to form a more or less continuous layer on the surface of the gills. These filaments may reach a length of at least 100 microns and are composed of long, rod-shaped bacteria joined end to end (fig. 18, E). They are colorless, transparent, and so difficult to distinguish that it requires very careful focusing under a high magnification to make them out as they lie closely, adherent to the surface of the gills. When an infected gill is examined on a slide the bacteria show no motion at first, but later the filaments begin to exhibit slow sinuous movements which are most marked at the ends of filaments which have

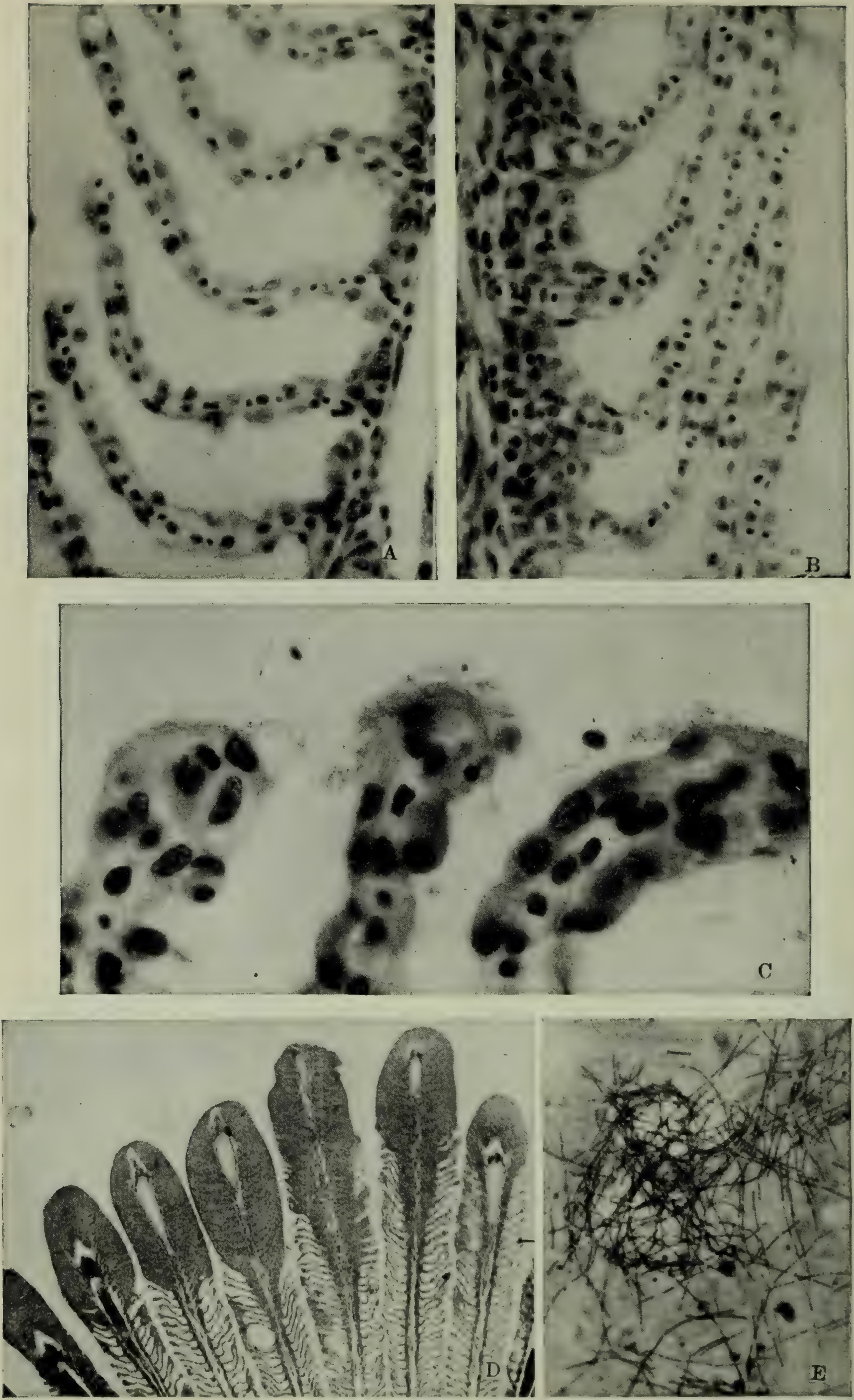

Figure 18.—For description, see opposite page.

become detached from the gills. These move slowly back and forth, sometimes accompanied by a sinuous bending of the entire filament. Attempts to isolate the bacteria in pure culture have so far been unsuccessful, but their general appearance is strongly suggestive of the myxobacteria.

The increased secretion of mucus accompanied by thickening and fusion of the gill filaments must seriously interfere with the circulation of water over the gills. To make matters worse, the mucus may become filled with sand grains and debris which must still further impede the flow of water. The free interchange of gases between the water and the blood is also seriously affected by the thickening of the epithelium, the water and blood being separated by many cells instead of 2 thin layers as in the normal gill. The result is serious interference with normal respiration, and it is probable that the high mortality is due primarily to this factor rather than to any toxic action.

Ordinarily, the bacteria are found only on the surface of the gills, but in the case of fry, they may occur also on the body and fins. This may account for the great destructiveness of the disease among fish of this age. In a number of instances the disease, within a few days of its appearance, caused virtually a total loss among fry.

According to Wolf (1944) this disease is caused by a deficiency of pantothenic acid in the diet and the presence of the characteristic bacteria is purely incidental. While it is possible that a dietary deficiency may be a contributing factor in some instances, the fact that a complete cure has been effected in hundreds of cases by destroying the bacteria without any change in the diet would seem to be a sufficient answer to Wolf's contention. Later, A. M. Phillips (unpublished report) confirmed Wolf's finding that a deficiency of pantothenic acid may cause hyperplasia of the gill epithelium but doubts if it has any relation to the bacterial disease (see page 73). Apparently Wolf failed to realize that there are at least two, and possibly more, types of gill disease.

CONTROL MEASURES

Inasmuch as the disease is caused by bacteria, which occur only on the surface of the gills and body, it should be more easily controlled than one that is due to internal parasites. This assumption is borne out by practical experience, as it has been found that the disease yields readily to treatment

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Photomicrographs of trout gills infected with bacteria: A. Cross-sections of lamellae of trout gill to show normal structure. Each lamella is composed of a middle layer made up of blood capillaries and supporting cells, covered on each side by a single layer of cells, the respiratory epithelium. x 340. B. Cross-sections of lamellae in early stage of infection by gill bacteria. The outer half of each lamella is fused with adjoining lamellae on both sides. Later they may become completely fused throughout so that the space at the base of the lamellae is obliterated. The epithelium also becomes greatly thickened. Bacteria can be seen indistinctly on the outer surface of the fused lamellae. x 340. C. Cross-section through the edge of lamellae more highly magnified to show presence of bacteria. The bacteria on the middle lamella have become dislodged from the surface, but on the other lamellae they can still be seen in close contact with the epithelium. x 680. D. Section through several gill filaments at a later stage of infection. The lamellae at the outer ends of the filaments have become fused into a common mass to form the enlarged ends so characteristic of the disease. On the lower part of the filaments the lamellae are still separate or fused only at the outer edge. x 25. E. Causative bacteria of gill disease as they appear in a dried smear made of scrapings from the gills. Note that the bacteria are arranged end to end to form long filaments. When living, it is impossible to distinguish the individual bacteria that form the filaments. x 680.

with copper sulphate. On the first appearance of the disease the fish should be dipped in a 1 to 2,000 solution of copper sulphate for 1 minute and then quickly transferred to running water. After the disease has become established, treatments on 2 successive days may be necessary to destroy all the bacteria. In such cases, it is impossible to avoid considerable mortality since by that time the gills have been injured so badly that many fish die even though the bacteria have been entirely destroyed. In the event that it is impracticable or undesirable to dip the fish in the manner just described, the disease can be controlled by use of a more dilute solution of copper sulphate in which the fish are held for one hour (p. 25). When properly handled, the treatment of fish in pools and raceways by such dilute solutions has been effective. This is especially true if the fish are treated on the first appearance of the disease, but after it has reached a more advanced stage, dipping in a stronger solution may be necessary.

A weak solution of potassium permanganate was recommended by Feustal (1935) as being superior to copper sulphate for treatment of gill disease. This was later confirmed by Frederic F. Fish (unpublished) who used the treatment on salmon fingerlings with marked success. The treatment as used by Feustal was very simple. Sufficient potassium permanganate was put in the head of the trough to make a 1 to 200,000 solution. The crystals were quickly dissolved by the inflowing water which was allowed to continue to flow at the usual rate. Fish lowered the strength of the solution to 1 part potassium permanganate to 400,000 parts water and adjusted the ratio of inflow per minute to volume of water in the trough or pool to 1:25. The treatment was repeated on 4 successive days.

When fish in a pool are to be treated, the chemical should first be dissolved in water and then sprayed over the surface of the pool. If the fish are in troughs, the crystals may be weighed out and added to the water at the head of the troughs, but it is much simpler to make up a stock solution which can be easily measured to provide the required amount for each trough.

Experiments by the writer with the treatment as used by Fish gave somewhat different results. The fish showed a noticeable improvement after the treatment, but it appeared that the bacteria were not killed, although they were loosened from their close attachment to the gill epithelium. As a result, most of the bacteria were sloughed off in the mucus, which probably accounted for the improved condition of the fish. It was evident that the number of bacteria was greatly reduced after each treatment and on the fifth day, only a few remained. Subsequently, however, the bacteria gradually increased until they were as abundant as before and it was necessary, after 2 to 3 weeks, to repeat the treatment. The same thing recurred after the second treatment and it was necessary to give a third or even a fourth treatment.

The results of these experiments indicate that it is possible to keep gill disease under control by flushing the troughs with a 1 to 400,000 solution of potassium permanganate on four successive days, but that it will probably be necessary to repeat the 4-day treatment at frequent intervals.

While it appears that treatments with potassium permanganate must be repeated more frequently than with copper sulphate, the former has the advantage that it can be used with less trouble and the treatment is much less toxic to fish. In fact, unless the fish are very weak, there is little mortality and most of them show no signs of injury.

It has been found that fry and fingerlings may contract the disease from older fish that appear to be perfectly healthy. Evidently, the bacteria may live in small numbers on such fish for an indefinite time without producing any noticeable effects. The fish act as carriers, and it is probable that in this way the disease in a hatchery is carried over from one season to the next. It is evident that the presence of carriers will make it very difficult, if not impracticable, to completely eradicate the disease from a hatchery.

Western Type of Gill Disease

Fish (1935) has called attention to a western form of gill disease which differs in several respects from the disease that is so prevalent at eastern hatcheries. In the last few years this disease has caused severe losses in several western States and is probably the most destructive hatchery disease in that region.

The lesions of the western type of gill disease are very similar to those of the eastern form except that alteration of the gill epithelium is not so extensive. The appearance of the gills as described by Fish is almost identical with that of gills in early stages of the eastern disease, but proliferation of the epithelial cells is not so marked and there is very little fusion of the gill filaments which is usually so noticeable in advanced stages of the eastern form of gill disease. Furthermore, the thread-like filaments, composed of slender, rod-shaped bacteria, that are always present on the gills in the eastern type of gill disease, have not been found in fish affected with the western variety. Fish has found 2 species of bacteria of very different appearance to be commonly present on the gills of the diseased fish, but has not yet been able to show that either is the cause of the disease.

Another respect in which the western type of gill disease differs from the common eastern form is that it does not respond to treatment with copper sulphate or potassium permanganate as does the eastern variety. In fact, it has been found that in several instances the loss among treated fish was actually much higher than among the controls that were not treated. Fish believes that the disease progresses relatively slowly at first, and that by the time the presence of the disease is recognized, the gills have become so altered that the fish are unable to withstand the additional rigors of treatment.

A somewhat similar condition of the gills has been described by Wales and Evins (1937). These authors termed the condition sestonosis, and believed that it was the result of irritation caused by diatoms and other small algal forms, bacteria, and protozoa.

Recently, A. M. Phillips (unpublished report) has confirmed an earlier observation by Wolf (1944) that a deficiency of pantothenic acid in the diet of trout may cause a marked hyperplasia of the gill epithelium similar to that found in western gill disease. When fish which had developed the typical lesions were fed a supplement of pantothenic acid, the disease soon disappeared. Phillips was unable to find any evidence that bacteria were connected with the disease and believed that he was dealing with the western type of gill disease.

To avoid any possible misunderstanding, it should be emphasized that there can be no question concerning the occurrence of the eastern type of gill disease at western hatcheries also, although it may have been introduced from the East. The author has received specimens of trout from hatcheries in the Pacific Coast States and in the Intermountain region that showed typical cases of eastern gill disease, including the presence of the characteristic bacteria on the gills.

References: Davis, 1926 and 1927; Fish 1935.

Cytophaga columnaris

This interesting species of bacteria was first described by the writer (Davis, 1922) as the cause of serious mortalities among fishes from the Mississippi River. Recently it has been grown in pure culture by Dr. Laura Garnjobst (1945) who has published a complete description of the organism. Her studies show that it is one of the myxobacteria which are characterized by long, slender rods surrounded by a slimy material secreted by the bacteria. The rods lack flagella, but nevertheless are actively motile.

Cytophaga columnaris attacks fish only at comparatively high temperatures. Garnjobst gives the optimum as 25° to 30° C. (77°–88° F.) and while it will grow at considerably lower temperatures, it is rarely injurious at temperatures below 65° F. Consequently, it is not ordinarily found on trout, but during the summer of 1940 an infection appeared among brook trout at the Leetown (W. Va.) hatchery. It reappeared during the summer of 1944 on brook trout in another raceway where the disease caused considerable mortality. In both raceways the temperature at times approached the upper limit for trout and it is evident that under such conditions *C. columnaris* may cause heavy losses. Infection with this organism has also resulted in serious mortalities among fingerling and adult salmon at Fish and Wildlife Service hatcheries at Leavenworth, Wash., and Coleman, Calif.

SYMPTOMS

The first indication of the disease is the appearance of a grayish-white spot on the head, gills, fins or some part of the body, which is usually surrounded by a zone with a distinct reddish tinge. Superficially, the spots resemble lesions produced by *Saprolegnia*, but a close inspection shows that they lack the fuzzy appearance so characteristic of a fungus infection. Infection frequently starts on the fins, the outer edges becoming lighter in color. This lighter area gradually extends toward the base, but there is no marked thickening of the epithelium to form a conspicuous white line as in the case of fin rot. On the contrary, the color appears to fade gradually. Eventually the fins may become frayed and ragged in appearance. Ordinarily, lesions first develop at the site of an injury, and the infection spreads from this point. For example, lesions on the trout at Leetown in 1940 appeared first around the mouth and caudal fin, apparently the result of injuries received in jumping.

CAUSE OF THE DISEASE

If a small amount of material is removed from a lesion and examined under a microscope, it will be found to contain large numbers of bacteria with a very characteristic appearance that makes them easily recognizable. The bacteria are long, slender, rod-shaped organisms 5 to 12 microns long and 0.3 micron wide (fig. 20, B). They are motile and can often be seen to move for a short distance in a straight line, accompanied by a sinuous bending of the body. One of the most characteristic movements is to turn one end slowly in a circle, the other end remaining stationary and forming a pivot on which the entire rod revolves. A modification of this movement can be seen at the surface of any aggregation of bacteria where individual rods wave rapidly back and forth.

One of the striking characteristics of the organism is the formation of columnar or dome-shaped masses of bacteria. When a bit of material, such as a scale, covered with bacteria is transferred to a slide, they soon collect in such masses around the edges, each column being separated a short distance from its neighbor. The free end of the column is usually rounded and sometimes appreciably enlarged. Similar aggregations of bacteria may be found on the surface of lesions, but in such cases they are usually shaped more like a haycock with a broad base (figs. 14, F and 19, B).

PATHOLOGY

As previously mentioned, infections with *Cytophaga columnaris* usually occur on the surface of the body or on the fins. The bacteria are found in greatest numbers in the connective tissues, but may also attack epithelial and other tissues. In most cases they apparently gain entrance to the dermal and muscular tissues through an injury to the epidermis, although it may be very slight. After reaching the dermis the bacteria multiply rapidly and penetrate the connective tissues in all directions. They occur in large numbers underneath the scales which drop off as the dermis is destroyed.

For obvious reasons, a study of the effect of *C. columnaris* on the tissues can be made more easily in scaleless fishes, such as the catfishes. A section through a well developed lesion on the common bullhead for example, shows that in the center the epidermis has been destroyed and the dermis more or less eroded. In late stages the dermis also may be destroyed exposing the muscles underneath. At the margin of the lesion the epidermis is breaking down as the bacteria move out from the focus of infection to invade uninjured tissues. The capillaries in the dermis become congested, followed by disintegration of their walls so that the blood fills all interstices in the surrounding tissues.

It is notable, however, that there is no hyperplasia of the epidermis around the lesions which is such a prominent feature of the lesions of furunculosis or ulcer disease. Proliferation of the epithelial cells of the body and gills is one of the most characteristic reactions to irritants of various kinds, but is entirely lacking in infections with *C. columnaris*. It is also of interest that the bacteria spread more rapidly in the dermis than in the epidermis so that the former is frequently heavily infected while the overlying epidermis is still intact. Figure 19, C shows a section of the infected dermis of a bullhead with the bacteria lying between the connective tissue fibers.

From the dermis the bacteria invade the skeletal muscles following the connective tissue (myocommata) between the muscle segments and thence along the connective tissues surrounding the muscle fibers. They may also enter the ends of the fibers, but this appears to be exceptional. As in the dermis, infection of the muscles is accompanied by congestion of the capillaries followed by hemorrhage. In the hemorrhagic areas large mononuclear leucocytes are especially abundant and there is considerable phagocytic activity. Phagocytes were observed which had ingested several bacteria, but apparently phagocytosis is very ineffective. Even before any bacteria can be found the muscle fibers begin to break down and shortly after the bacteria appear in any numbers all cellular elements, including the phagocytes, are destroyed.

Owing to differences in the structure of the tissues, lesions on the gills follow a somewhat different course. Gill lesions frequently start at the distal end of the filaments and extend toward the base. At the same time they spread out laterally until a large part of the gill may be involved (fig. 14, E). Sometimes the gill cover may also become infected, causing erosion of the soft parts, beginning at the outer edge. In striking contrast with the condition in true gill disease, there is no thickening of the epithelium, but the epithelial cells in the immediate vicinity of the lesion become strongly vacuolated (fig. 19, A). This characteristic reaction occurs before any bacteria can be found on the cells. Later, as the bacteria advance over the epithelium, (fig. 20, A) the lamellae are entirely destroyed, followed by distintegration of the filaments. As in infections of the integument, the blood vessels are greatly congested, resulting in extensive hemorrhage when the filaments break down. In figure 19, D the bacteria can be seen invading the cartilaginous axis of the filament which is being eroded by lytic action. Covering both gill and body lesions is a dirty-white layer composed of bacteria, partially broken down cells and debris held together by the slime secreted by the bacteria. Frequently, the bacteria are aggregated to form the elevated or haycock-like structures (figs. 14, F and 19, B) previously mentioned. These are composed of practically a pure culture of *C. columnaris* with great numbers of pycnoidal nuclei which appear to be derived chiefly from erythrocytes.

It was formerly believed that healthy, uninjured fish do not become infected with *C. columnaris,* but evidence is accumulating that this may not be true in all cases. There is no evidence that the trout at Leetown which became infected during the summer of 1944 had been injured in any way and except for the presence of the disease they appeared to be in excellent condition, although it is possible that the relatively high temperature of the water may have lowered their vitality. Even stronger evidence that the disease may attack healthy fish is provided by an outbreak among white crappie (*Pomoxis annularis*) in Coolidge Lake, Ariz. It was reported that in August 1942, thousands of crappies died in the lake although other fishes were not affected. Specimens of diseased fish sent to the writer showed a heavy infection on the gills with *C. columnaris* which was evidently the cause of the mortality. It appears that in this case the disease reached epidemic proportions and it is not impossible that many mortalities of fish during warm weather may be caused by infection with *C. columnaris.* Of course, so many parasites occur on the gills that it is always possible that the infection followed some slight injury, but in both cases no parasites, other than bacteria, could be found.

Nevertheless, the fact remains that infections are most likely to occur when fish are handled or otherwise injured at water temperatures above 70° F. The lesions usually appear within 24 hours and death follows within 48 to 72 hours. At lower temperatures the danger of infection is much less and the disease develops more slowly. The lesions, however, are liable to a secondary infection with fungus *(Saprolegnia)* which may prove more injurious than the original infection.

CONTROL

If there is reason to believe that fish may become infected as a result of handling, this can be prevented by dipping the fish at the time in a 1 to 2,000 solution of copper sulphate for 1 to 2 minutes. Where properly done, this will afford almost complete protection from the disease and is routine practice at some warm-water hatcheries when fish are handled during the summer. After evidence of infection appears, fish may be cured by the same treatment if the disease is not too far advanced, but 2 or 3 dippings at 12- to 24-hour intervals may be necessary. It is not possible to cure fish with extensive lesions or infected gills and such fish should be destroyed at once. Further progress of the disease can be checked by transferring the fish to cold water, and with trout and salmon this is usually the best method of control.

References: Davis 1922; Garnjobst 1945.

MISCELLANEUOS DISEASES, INCLUDING THOSE OF UNCERTAIN ORIGIN

Fungus Diseases

Trout, like most fresh-water fishes, are attacked occasionally by fungus or water molds (Saprolegniacea). Probably the species most frequently found in trout is *Saprolegnia parasitica* Coker which may attack both the eggs and fish. Formerly, it was thought that this was the only species parasitic on fish, but it is now apparent that several species may infect trout and other fishes, although, owing to the difficulty of making specific distinctions, the matter is still far from being settled.

Although *Saprolegnia parasitica* often causes heavy losses among trout of various ages, it is doubtful whether the fungus is the primary cause of the trouble. Any physical injury or infection by external parasites may enable this fungus to obtain a foothold on the fish and then to spread from the original site of infection. Susceptibility to infection is greatly increased if the fish are suffering from general debility or are living under unfavorable conditions. The fungus may develop on any part of the fish, and usually occurs in small patches, but in late stages may cover a large area. Ordinarily the fungus appears as a tuft of white threads which radiate from the body of the fish for a distance of about one-third of an inch or even more. When the water is somewhat roily, sediment and debris may become entangled among the fungal filaments so that the fungused areas may appear a dirty gray or brown. The fungus is attached to the fish by means of small, root-like filaments which penetrate the skin, and in late stages of the disease may invade the underlying subcutaneous muscle. As the filaments grow through the skin, they cause the death of the surrounding tissues and thus form large necrotic areas which may eventually cause the death of the fish.

The eggs of fish are also subject to attack by *Saprolegnia,* and at most hatcheries the heaviest losses from fungus occur at this stage. There is no evidence that *Saprolegnia* can begin to develop on a normal, healthy egg unless there is some foreign organic matter adhering to the surface. However, it develops very quickly on any dead eggs that may be present, and from these the mycelial filaments spread rapidly to adjoining healthy eggs, which are soon killed. Consequently, within a comparatively short time, a large number of eggs may become bound together in a mass by entangling filaments, which continually spread farther and farther from the original site of infection.

The fungus reproduces by means of minute biciliate zoospores which are produced in enormous numbers in enlarged, club-shaped ends of the filaments, known as zoosporangia, and it is these zoospores that enable the fungus to spread from fish to fish. Another method of dissemination of the fungus is by means of resting cells or chlamydospores. These cells, which develop in long chains, readily separate from each other and may then give rise to hyphae or to zoospores. In addition to these methods of asexual reproduction, *Saprolegnia* reproduce sexually through the formation of egg-like zoospores which, after being fertilized, develop into mycelia similar to those formed by the zoospores. The sexual type of reproduction occurs very rarely in the fungus found on trout and from the practical standpoint is consequently of little importance.

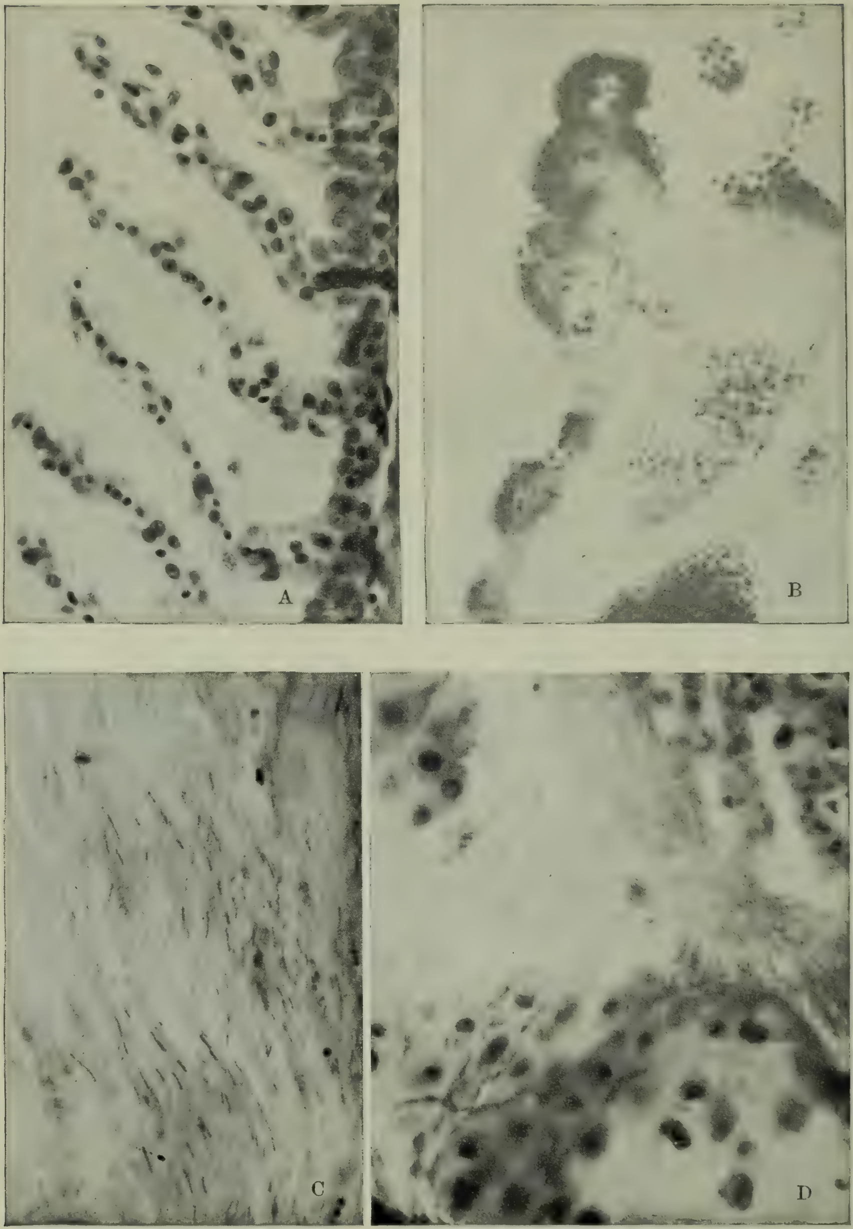

Figure 19.—For description, see opposite page.

Another species of fungus which has evidently been confused with *Saprolegnia parasitica* in the past has been described by Davis and Lazar (1940). This fungus, which has been named *Saprolegnia invaderis,* was found in small fingerling trout at the Leetown (W. Va.) hatchery. Infection occurs through the alimentary tract from which the fungus grows out through the abdominal wall to the exterior. In most cases, the fungus first starts to grow in the lumen of the stomach, but occasionally it grows in the intestine as well. In a short time branched hyphal filaments extend throughout the lumen of the stomach and then begin to grow through the stomach wall destroying any tissues that may lie in their path (fig. 20, D). Once through the stomach wall, the hyphae pass through the body cavity and then through the body wall of the fish to the exterior (fig. 20, C). Irritation set up by the fungus as it grows through the tissues causes congestion of visceral blood vessels and accumulation of blood in the infected organs. Ordinarily the hyphae do not reach the exterior until after the death of the host. At this time the appearance of the fish is characteristic, the abdomen being covered with a fuzz-like growth of short hyphae (fig. 20, E) which in a few hours may extend all over the body. Zoospores and chlamydospores develop on the emergent hyphae and provide for the dissemination of the parasite to healthy fish. Apparently, no reproductive bodies are formed within the body of the host.

This species has in one instance been found also on the gill of an adult trout where it had formed a small, necrotic area. There was no evidence that the gill had been injured in any way, and it is possible that this fungus may attack other organs besides the alimentary tract. It is evident that, unlike *S. parasitica, S. invaderis* is able to develop without previous injury to the tissues that are infected.

CONTROL

Consideration of any treatment for the control of fungus must take into account the cause of the infection. If the presence of fungus is due to a secondary infection following injuries produced by some other parasite, it is obvious that a permanent cure will be impossible unless the cause of the original infection is removed by appropriate means. On the other hand, if fungus is the primary cause of the trouble, eradication of this parasite must be the chief concern. The results reported from the use of various chemicals for ridding fish of fungus are frequently contradictory. No doubt this has been due, in

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Photomicrographs of *Cytophaga columnaris:* A. Section of gill lamellae near bacterial lesion. Although no bacteria can be seen on the lamellae, the epithelial cells are strongly vacuolated. This characteristic reaction to *C. columnaris* is very different from the reaction of the epithelial cells to gill bacteria. Compare with figure 18B. x 340. B. Section through mass of bacteria covering outer surface of lesion on trout gill. The gill filaments underneath have been destroyed and only the partially disintegrated nuclei of the tissue cells remain. The dark mass at the lower side of the figure is the remains of a blood clot. Note that on the surface the bacteria have collected in chunks with a rounded convex surface. The dark objects at the base of these masses of bacteria are the nuclei of tissue cells. x 340. C. Section of dermis of skin of bulhead infected with *C. columnaris.* The bacteria have invaded the connective tissue which has not yet begun to break down. Note that the bacteria are arranged with their long axis parallel to the connective tissue fibers. x 680. D. Section through the gill filament of a trout infected with *C. columnaris.* The epithelium has been entirely destroyed and the bacteria are now invading the cartilaginous axis of the filament by lysing the cartilage. Note the presence of bacteria between the cartilage cells in the lower left-hand part of the figure. Above this region the cartilage has been entirely destroyed and the space is occupied by masses of bacteria. x. 680.

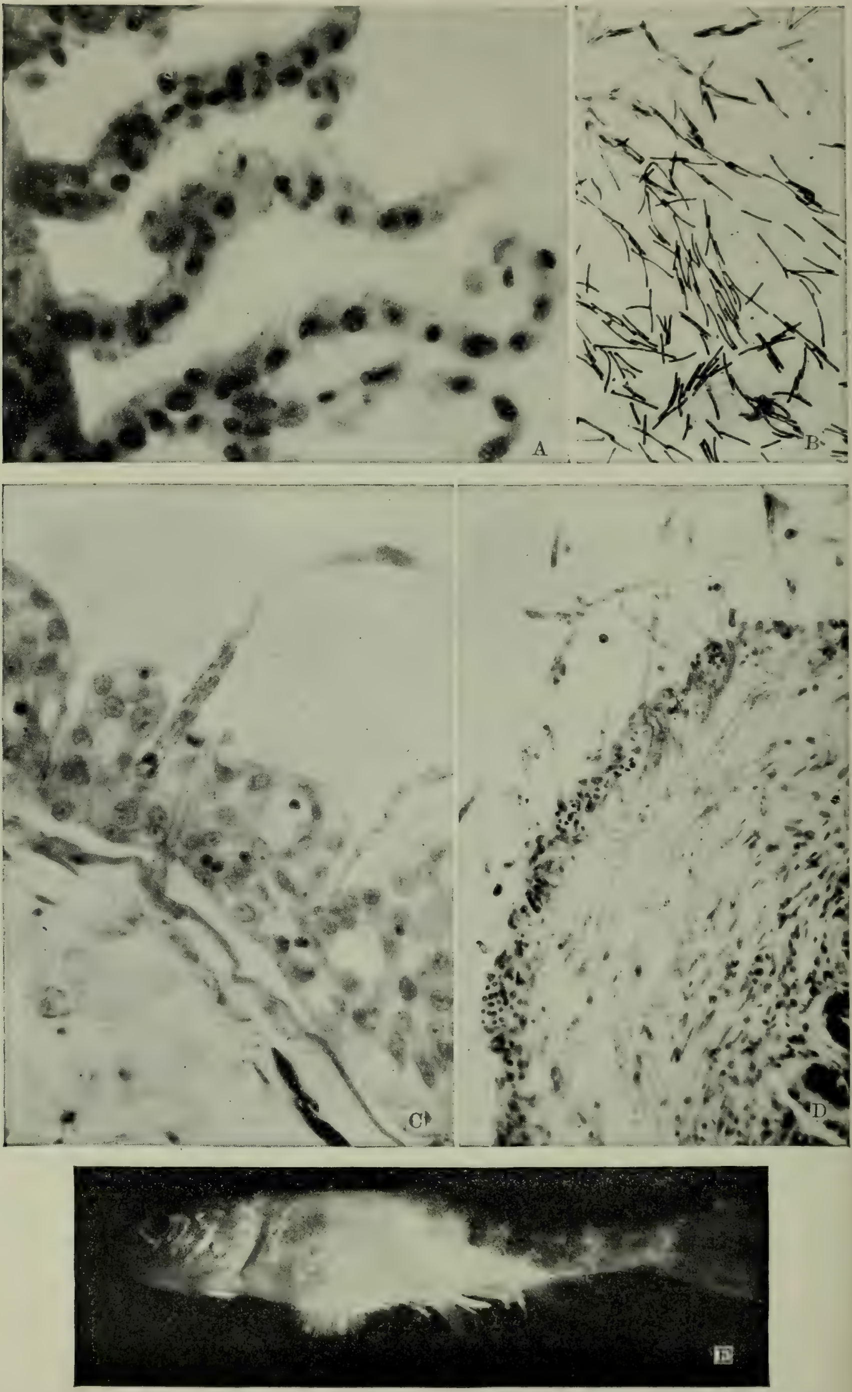

FIGURE 20.—For description, see opposite page.

part, to the fact that different species of fungi were involved and also to the stage and degree of infection. After the parasite has penetrated deeply into the tissues, it is obviously much more difficult to eradicate than at an earlier stage. Furthermore, infections of such vital organs as the gills are particularly injurious and difficult to combat.

At most hatcheries the usual treatment for fungus has been to expose the fish to a strong solution of salt (sodium chloride), which was accomplished in various ways. Probably the best method is to dip the fish in a 3-percent salt solution until they show signs of distress. In early stages of the disease one such treatment is usually effective, but if the fungus is well established, even several successive treatments may not effect a cure. Dipping the fish for 1 minute in a 1 to 2,000 solution of copper sulphate has proved effective in some instances. Schneberger (1941) reports good results in preventing infection of trout eggs by the addition of an ounce of a saturated solution of copper sulphate to the water entering a battery of eggs. Malachite green is said by several investigators (Foster and Woodbury, 1936; O'Donnell, 1941) to be the most effective agent yet used for the control of fungus. O'Donnell recommends that the fish be dipped in a 1 to 15,000 solution of malachite green (zinc free) for 10 to 30 seconds. He found that this treatment was non-toxic to 18 species of fish (including trout) upon which it was used. In most instances, one treatment was sufficient to completely rid the fish of fungus and promote healing, but occasionally it was necessary to give 2 or 3 dips at intervals of 2 days.

In dealing with fungus, however, by far the most effective method is to prevent the development of the disease, and in most cases this is a comparatively simple matter. As previously mentioned, there is reason to believe that healthy, uninjured fish are not affected by fungus; but infection is very likely to follow any mechanical injury, even though very slight. Once the protective mucous covering of the fish is broken, an opportunity is afforded for the zoospores to germinate and penetrate the epithelium at the point of injury. From this focal point the mycelium then invades the surrounding uninjured tissues.

Infection as a result of physical injury is especially liable to occur during or shortly after the spawning season. Not only is it almost impossible to avoid slight injuries to the fish as a result of handling incident to stripping, but the vitality of the fish is usually lower at this time than at other seasons, so that they are especially susceptible to infection. Fortunately, the danger of developing a fungus infection in spawned fish can be greatly decreased by dipping them in a 1 to 15,000 solution of malachite green, or in a 3-percent salt solution after they have been stripped.

Photomicrographs of *Cytophaga columnaris* and *Saprolegnia invaderies:* A. Section of gill lamellae of trout infected with *C. columnaris*. The epithelium has been destroyed, only the capillary network being left, and this is already beginning to disintegrate. The bacteria appear as dark lines or dots on the surface of the cells. Compare with fig. 19, A. x 680. B. *C. columnaris,* photographed from a dried smear made from a lesion on the surface of the body. x 800. C. Section of the abdominal wall of a fingerling trout infected with *Saprolegnia invaderis*. The fungus hyphae can be seen growing through the skin. The epithelium is much thicker than normal. x 340. D. Section through wall of trout stomach which has been penetrated by fungus hyphae. The thick, muscular part of the wall is filled with a network of hyphae extending in all directions. Outside the stomach in the body cavity there is a luxuriant growth of branching hyphae. Note the congested blood vessels in the outer layer (serosa) of the stomach wall. x 170. E. Fingerling trout showing fungus hyphae growing out through abdominal wall. The lighter color of the body anterior to the anal fin is characteristic and is caused by hyphae growing through the skin. Somewhat enlarged.

Under ordinary circumstances *Saprolegnia* can be prevented from causing any considerable injury to incubating eggs by carefully removing all dead eggs at frequent intervals. If this is done, there will be little opportunity for the fungus to become established. Care should also be taken to prevent the eggs from becoming covered with sediment or debris. This not only tends to smother the eggs but also affords an opportunity for the development of bacteria and protozoa, which may so injure the eggs as to make them susceptible to infection by *Saprolegnia.*

One of the most effective weapons in combating fungus is to keep the ponds and troughs in a sanitary condition. Any surplus food or dead fish which are allowed to remain in the ponds for any length of time become covered with a luxuriant growth of fungus, which, of course, results in the formation of enormous numbers of zoospores. These are continually being set free in the water, so that the slightest wound on any fish present is very liable to become infected.

The control of *S. invaderis* is a comparatively simple matter and no special treatments are necessary. Since zoospores and chlamydospores are not formed until 24 to 48 hours after the death of the fish, it is necessary only to remove all fish within a few hours after death, to prevent the infection from spreading to healthy fish. Failure to do this may easily result in a rapid spread of the infection, as the habit fingerlings have of nibbling at their dead comrades, provides an ideal method of infection.

References: Clinton, 1894; Davis and Lazar, 1940; Kanouse, 1932; O'Donnell, 1941.

Popeye

"Popeye" is a popular term applied to fish that show a marked protrusion of the eyeballs, a condition known as exophthalmos. This disease is common among fingerling trout at some hatcheries and may occur also among yearlings and adult fish.

There are undoubtedly several forms of popeye disease, due to causes quite different. One form, caused by a severe infestation with the larvae of a trematode worm, has already been referred to in the section on parasitic worms. Another type of popeye, often called "gas bubble" disease, described by Marsh and Gorham (1905), may occur when the water supply becomes supersaturated with air. Most spring waters are more or less deficient in dissolved air, but occasionally the water may be supersaturated. In such cases, there is a tendency for nitrogen gas to collect in various parts of the body, including the loose connective tissues surrounding the eyeball, causing the latter to protrude from its orbit. This form of popeye can be easily prevented by installing an efficient deaerating device, which will allow excess gas to escape from the water. It is also claimed that in waters supersaturated with oxygen this gas may form bubbles in the tissues and give rise to symptoms similar to those produced by nitrogen (Plehn, 1924; Woodbury, 1941).

Still another form of popeye results from an accumulation of serous fluid in the abdominal cavity and other parts of the body. In this form, the abdomen becomes greatly distended and when opened, is found to be filled with a watery fluid. This is probably the most common form of popeye in trout and in all cases observed by the writer has been found associated with a diseased condition of the kidneys. The kidneys of the affected fish are usually darker in color than normal, due to the accumulation of pigment, and the tubules contain casts and crystals, probably of some calcium salt. In places, the epithelium lining of the kidney tubules may be entirely disintegrated. The cause of of this disease is unknown, no evidence having been discovered that it is due to a specific infection of any kind. Trout showing this type of popeye have in several instances shown a marked improvement following the addition of 1½ to 2 percent of cod-liver oil to the diet. This suggests that the disease may possibly be connected in some way with calcium metabolism, especially as it appears to occur only at hatcheries supplied with water having a high calcium content.

Recently, the writer observed a fourth kind of popeye in fingerling trout, characterized, as in the previous case, by the accumulation of serous fluid in the abdominal cavity and around the eyeball. Here, however, the resemblance ends, as the kidney tubules do not contain the characteristic casts and crystals observed in previous cases, but on the contrary, show a heavy infection with a myxosporidian parasite. It has not yet been determined whether or not this parasite is the cause of the popeyed condition.

Several writers have held that certain forms of popeye are due to bacterial infections of the eye, but there is still considerable doubt whether this is the case. In a study of popeye by Williamson (1927) the investigator isolated 22 strains of bacteria from the diseased eyes of fishes, but concluded that none of them could be proved responsible for the gas-bubble disease.

A type of popeye quite different from any previously described has been reported by Belding and Merrill (1935) as having caused considerable mortality among brook and rainbow trout at a Massachusetts hatchery. In this disease less than half the fish (20-30 percent) show a marked exophthalmos (protrusion of the eyeballs). While it may affect practically all tissues of the body, the disease shows a selective affinity for the kidney, and any changes in other tissues may be largely the result of impaired renal function.

The most characteristic symptom of this disease appears to be the accumulation of serous fluid in various parts of the body. In addition to exophthalmos, blisters may form on the surface of the body, which appear as raised circular or elliptical areas of skin, separated by fluid from the underlying tissues. These blisters may appear on any part of the body except the head, tail, and fins, but usually on the sides above the lateral line. They may contain a clear amber or reddish fluid, or purulent material consisting of cells, bacteria, and granular debris. Abscesses, filled with a white or bloody turbid fluid may occur deep in the muscles. These are found most frequently in the neighborhood of the kidneys and in the ventral triangle between the pectoral fins.

Practically all the internal organs may be involved, particularly the kidneys, serous cavities, liver, and spleen. The kidneys are most frequently affected, over 50 percent of the cases showing gross lesions consisting of abscesses filled with a grayish-white material. Similar abscesses may occur in other organs.

It is apparently a chronic infectious disease, but the cause has not been definitely determined. Probably, however, the causative agent is a bacterium which is difficult to cultivate. Bacteria, isolated from the diseased tissues, proved pathogenic to trout, causing death in about 3 weeks; but in no case was the typical disease produced by inoculation with cultures.

The disease is seasonal in character, the mortality being confined to spring and early summer. It affects chiefly adult fish, and brook trout appear to be somewhat more susceptible than rainbows.

References: Belding and Merrill, 1935; Marsh and Gorham, 1905; Williamson, 1927; Woodbury, 1941.

Thyroid Tumor or Goiter

This disease, which is characterized by enlargement of the thyroid gland, was at one time believed by some investigators to be of a cancerous nature. It is now universally conceded, however, to be analogous to goiter in man and to have no relation to cancer. The belief in the cancerous nature of thyroid enlargement in trout was largely due to the peculiar structure of the gland in fishes. Unlike the thyroid of higher animals, this gland in fishes is not surrounded by a definite capsule. On the contrary, the cells form a branching structure, which extends into the surrounding tissues. When the gland becomes enlarged, it has a striking superficial resemblance to a malignant growth, since it appears to invade the surrounding tissues in a similar manner.

The thyroid is a small, ductless gland that produces an internal secretion essential to the health of the animal. It is situated beneath the floor of the mouth between the first and third gill arches. Owing to its small size and the separation of its units, which are distributed among other tissues, it is not recognizable by the naked eye.

The first external indication of thyroid enlargement is a red streak or spot on the floor of the mouth near the second pair of gill arches. This red area is due to an increased blood supply to the enlarging thyroid and may appear in fish only 2 months old. This is followed by an external swelling, which may become visible as a cone-shaped, reddish tumor on the ventral side of the head just beneath the gills. Sometimes the tumor first appears on the floor of the mouth, and secondary growths frequently occur on the gills and at the anterior end of the lower jaw. The tumors do not become externally visible before the fish are at least 6 months old, and only rarely do they become noticeable before the fish are a year old. The greatest number of goiters are said to appear during the second and third years of life, probably due to the fact that the thyroid is most active in rapidly-growing fish. In older fish the activity of the thyroid decreases, and the tumor may decrease in size and disappear, the fish making a spontaneous recovery. Large tumors often become abraded, which results in infection by fungus or bacteria.

The primary cause of thyroid tumor is now generally conceded to be a deficiency of iodine, which is essential to the proper functioning of the thyroid gland. There is also evidence that overcrowding, overfeeding, a limited water supply, and insanitary conditions in the ponds are important contributing factors.

CONTROL

Since the causes of the disease are so well understood, its control is a comparatively simple matter. Wild trout virtually never show any evidence of goiter, and hatchery fish in early stages of the disease show immediate improvement when liberated in natural waters.

Inasmuch as a deficiency of iodine is the principal causative factor, it is essential that this condition be corrected at once. This can be done by adding small quantities of a solution of iodine to the water, but the addition of iodine directly to the food is much simpler and apparently gives equally good results. The form in which the iodine is administered appears to make little difference. At the Federal hatcheries, very good results have been obtained with the so-called Lugol's solution, which consists of 1 percent iodine dissolved in a 1-percent solution of potassium iodide. A tablespoonful of this solution thoroughly mixed with 50 pounds of ground food is sufficient to keep the fish from showing any trace of thyroid tumor.

When such products as shrimp meal, salmon meal, white fish meal, or kelp meal, which are rich in iodine, are fed to the fish, it is, of course, unnecessary to add iodine to the ration. Even a comparatively small percentage of these iodine-rich products will serve to protect the fish from goiter.

References: Marine and Lenhart, 1910 and 1911; Marine, 1914; Marsh, 1911; Gaylord and Marsh, 1914.

Intestinal Inflammation

Trout in rearing pools at times suffer a heavy mortality which is apparently due to impairment of the digestive functions. The blood vessels of the intestine become congested, particularly at the lower end; the pyloric caeca may also be similarly inflamed; and the gut becomes filled with mucus and blood. In severe cases, patches of the intestinal lining may be entirely destroyed. The vent is usually enlarged and there is a copious discharge of mucus. Both flagellate and intracellular stages of *Octomitus salmonis* may be abundant, but it is not believed that this parasite is the primary cause of the disease, as many fish exhibiting these symptoms may be only slightly infected, or not at all. It is probable, however, that infection with *Octomitus* may frequently be an important contributing factor.

In severe cases of the disease the fish dart rapidly through the water and frequently jump out on the banks. In more chronic cases the fish refuse food; grow dark in color; and become more susceptible to attack by parasites. In such cases they may lie quietly about the pond, gradually growing weaker, until they succumb.

The disease is evidently caused by an unsuitable diet and is probably the result of a vitamin deficiency. At present, however, there is little evidence available as to the particular vitamins involved.

Fatty Degeneration of the Liver

This disease, called also lipoid degeneration, has been known for some time in Europe, where it has caused heavy losses, but apparently has only recently become a serious factor at American hatcheries. It affects chiefly rainbow trout, rarely brook or brown trout.

SYMPTOMS

The diseased fish are usually darker in color than normal and in advanced stages float listlessly at the surface of the water. The gills, on the other hand, are much lighter than normal and in extreme cases may have only a very light pink color. This is due to a marked anemia which is one of the most characteristic symptoms of the disease.

On dissection, the stomach and intestine are usually found to contain little, if any, food, but are filled with a pale yellow fluid. The body cavity is frequently distended with a similar fluid which may result in a noticeable exophthalmos, or protrusion of the eyeball.

The most striking feature of the disease is the appearance of the liver which typically is light yellow or yellowish gray. This coloration may be uniform over the entire organ, but not infrequently, there are scattered, dark red blotches, which give the liver a peculiarly mottled and very characteristic appearance.

PATHOLOGY

The characteristic yellow color of the liver is due to the deposition of lipoids in the liver cells, where they replace the glycogen normally stored in these cells. Lipoid is a general term applied to a number of fat-like substances which differ from true fats in containing nitrogen, as well as in other respects. In severe cases, lipoids may accumulate to such an extent as to cause extensive degeneration of liver cells. Frequently, the lipoids, instead of being evenly distributed throughout the liver, are concentrated in certain areas, causing the mottled appearance. According to Gaschott, who studied the disease extensively in Germany, lipoids may be deposited also on the heart in angular masses.

The appearance of the gall bladder may vary greatly in this disease. In some cases it may be distended by a clear, colorless secretion, in others it may be shrunken and contain only a little orange-yellow liquid. Gaschott states that the disease is frequently accompanied by intestinal inflammation, since the fish eat with unimpaired appetite, but are unable to digest their food.

The pink color of the gills is due to anemia which, in advanced cases, may be so severe that very little, if any, blood flows when the blood vessels are cut. This condition may result in a sudden increase in mortality, when for any reason the oxygen content of the water falls below normal.

CAUSE OF THE DISEASE

The disease is evidently caused by malnutrition as the result of overfeeding or the use of unsuitable diets. A deficiency of vitamins in the diet is probably an important factor. German investigators have found that the disease is more likely to result from the use of certain foods, especially from those rich in fats, than from others. The more extensive use of vitamin-deficient dry meals with too little fresh meat in the diet may be responsible for the recent increase in the disease at American hatcheries.

Gaschott found that low temperatures are often an important factor in bringing on an outbreak of the disease, and in this country it appears to be most prevalent during cold weather. This is easily understood, since at low temperatures metabolism is slowed, and fish are unable to utilize their food as rapidly as at higher temperatures.

One of the most remarkable characteristics of lipoid degeneration is that it appears to be confined largely to rainbow trout. However, evidence is accumulating to indicate that brook and brown trout may not be as immune to this disease as was formerly believed. In these fishes the disease apparently occurs in a more insidious form and its presence is less easily recognized than in rainbow trout. It is well known that both brook and brown trout are frequently injured by improper feeding and, in some cases, at least, may show definite symptoms of lipoid degeneration.

CONTROL

In dealing with lipoid degeneration, it is important to remember that there are reasons for doubting that fish which have suffered from a severe attack of the disease ever fully recover. There is such extensive degeneration of the liver that it may not be possible for the organ completely to regain its normal condition. At any rate, it must require time before the organ is able to function again as it should.

Since the disease is a nutritional disorder, it is obvious that prevention and cure depend on the use of suitable foods in proper amounts. Many fish culturists overlook the fact that a considerable percentage of dry meals in the diet makes a more concentrated food and, consequently, there is more danger of overfeeding than with the diets formerly used. However, with proper care in feeding, and the use of balanced diets which have a sufficient vitamin content and are readily digested, there is no reason to believe that the use of dry foods will have any harmful effect.

On the first appearance of the disease, it is advisable to reduce drastically the amount of food fed and, if dry foods are being used, to increase the proportion of fresh meat. The composition of the diet should be carefully scrutinized to determine whether or not it is deficient in any essential element. Gaschott found that periodical changes in the diet were very helpful in controlling the disease. He emphasizes the fact that trout should not be fed heavily during the winter, and in times of severe cold, believes it best to stop feeding altogether. Even though this may check their growth, he considers it preferable to running the risk of bringing on an outbreak of the disease.

References: Hayford and Davis, 1936; Gaschott, 1929, 1931.

Acute Catarrhal Enteritis

M'Gonigle (1940) has called attention to a disease which is the cause of serious mortalities among small fingerlings at Canadian Maritime hatcheries. According to this investigator, enteritis is an exceedingly acute intestinal disease of very young salmonid fishes, particularly brook trout, which have been feeding only about 2 to 3 weeks, although older fingerlings in the hatchery may be attacked at the same time.

SYMPTOMS

The most characteristic symptom of the disease is a very violent whirling and "corkscrewing" of affected individuals which is so violent that the fish appear to be writhing with pain. After two or three of these violent contortions, the fish, breathing rapidly, sink quietly to the bottom. Several convulsions may occur in rapid succession followed by the death of the fish. Sometimes the whirling may be less violent and, in cases where "pin heads" are dominant, may be scarcely noticeable. Apparently the largest and finest fingerlings become affected most acutely. No other symptoms were observed by M'Gonigle.

PATHOLOGY AND CAUSE OF DISEASE

Pathological changes are confined to the intestine. There is always a marked increase in the mucus secretion in the anterior part of the intestine and simultaneously a complete stoppage in the flow of bile. As a result, the mucus in the upper gut, instead of being stained a greenish or brownish yellow is clear and colorless. Bacteria may be more abundant than usual in the intestine, but there is no evidence that they have any causal connection with the disease.

Although no definite cause is known, all available evidence seems to indicate that foods and feeding are important factors. M'Gonigle believes that the disease is associated with rapid increases in temperature which occur in the spring or early summer at hatcheries which are supplied with water from streams. Enteritis seems to be more severe in hatcheries having a late hatch followed by rapid and marked warming of the water. It is less common at spring-fed hatcheries where no such changes in water temperatures occur. The disease affects chiefly the eastern brook trout, although it has been observed in other species, especially the Atlantic salmon, *Salmo salar*.

M'Gonigle emphasizes the fact that enteritis has frequently been confused with octomitiasis, but this does not necessarily mean, as M'Gonigle seems to assume, that all mortalities among small fingerlings which have been attributed to infection with *Octomitus* were, in reality, due to acute enteritis. In fact, many of the hatcheries at which heavy losses from octomitiasis have been reported are spring-fed and, consequently, do not experience the rapid increases in temperature which M'Gonigle found to be ordinarily associated with the disease.

CONTROL

No satisfactory treatment or preventive is known and until more has been learned about the cause of the disease, little progress in that direction can be expected. M'Gonigle recommends that affected fish be planted in small streams where they can get natural food such as insect larvae. Since the disease is not due to infection by animal parasites or by bacteria, liberation of the fish in natural waters can do no harm.

References: M'Gonigle, 1940.

Anemia

Anemic trout are not uncommon under hatchery conditions. The gills become pale pink or even grayish-white, frequently followed by the death of the fish. The appearance of the gills is due to a great reduction in the number of red blood corpuscles, which give the blood its characteristic color.

According to Tunison and Brockway (1943), different species of trout show considerable variation in the normal number of red blood cells. They found that in healthy hatchery fish, rainbow trout showed the highest count with an average of 1,220,000 red corpuscles per cubic millimeter. Brook trout were second with an average count of 1,032,000 followed by brown trout with an average of 766,000. Lake trout gave the lowest count with an average of only 642,000 red cells per cubic millimeter. Plehn (1924) states that for normal trout the number of red corpuscles is approximately 1,500,000 per cubic millimeter.

Anemia may be due to various causes. It is characteristic, for example, of fatty degeneration of the liver, and may result from heavy infections with animal parasites. There is no doubt, however, that in many instances anemia is primarily the result of dietary deficiencies. When fed a synthetic diet containing no fresh meat, Phillips (1940a) found that the red cell content decreased rapidly and the fish began to die during the sixth week when the count was 710,000 per cubic millimeter. The mortality increased rapidly as the red-cell count continued to decrease. After the blood count reached 557,000, fresh beef liver was added to the diet at a 50 percent level and the mortality gradually decreased as the blood count rose. When the red cells reached 700,000 per cubic millimeter, the mortality ceased. It will be noted that the mortality began and stopped at practically the same red cell content, which would indicate that serious mortality may be expected when the red-cell count drops below 700,000 per cubic millimeter.

It was found that fresh beef liver was an effective cure in all cases of anemia brought on by elimination of fresh meat from the diet. Maggots of the house fly (*Musca domestica*) also cured the anemia in a short time. Tunison and his coworkers (Tunison *et al*, 1943) conducted a series of experiments in which attempts were made to cure anemia with various vitamins of the B-complex. As a result of these experiments it was concluded that trout anemia is caused by a multiple vitamin deficiency and that a combination of riboflavin, pantothenic acid, and pyridoxine is required to restore a normal blood count. However, later experiments (Tunison *et al*, 1944) indicate that other factors besides these three vitamins are involved in the anemia picture of trout.

References: Bridge, 1943; Phillips, 1940a; Phillips and Tunison, 1940; Tunison *et al*, 1943 and 1944; Simmons and Norris, 1941; Wales and Moore, 1943.

White-Spot Disease

The white-spot disease occurs in both eggs and fry and is characterized by the appearance of an opaque or white area in some part of the embryo, usually the yolk. The opaque area is very noticeable in the semi-transparent yolk, so that the disease is easily recognizable even in its early stages. White-spot may occur at any stage of development up to the complete absorption of the yolk sac, but is more likely to appear during the early stages.

There is still considerable uncertainty regarding the cause of this disease, and it seems probable that it is not always due to the same agency. The characteristic white spot in the yolk is due to coagulation of the transparent yolk, causing it to become opaque. In many instances, the coagulated yolk contains one or more kinds of bacteria, but this is by no means always the case. Frequently numbers of the so-called "periblast cells" which are instrumental in the absorption of the yolk, are present in the white spots.

The evidence points strongly toward the conclusion that white-spot is primarily caused by some injury to the eggs. Such an injury might produce coagulation of the yolk followed by increased activity of the periblast cells. If the egg membrane, or in the case of the fry, the layer of cells surrounding the yolk, is ruptured or perforated, any bacteria present may gain entrance and develop in the yolk, which, of course, is simply non-living organic material.

The fact that several kinds of bacteria may occur in the white spots and that no one kind appears to predominate is strong evidence that the disease is not due to a specific infection. Furthermore, there is no indication that the disease is contagious, as is shown by the random distribution of diseased eggs among those that are perfectly normal.

It is well known among trout culturists that white-spot is most likely to occur in eggs that have been shipped a considerable distance or that have been handled roughly. This, of course, is in complete accord with the theory that the disease is usually the result of physical injuries. There is also evidence that in some cases the disease may have been the result of the chilling or freezing of the eggs.

Reference: Leach, 1924.

Blue-Sac Disease

The blue-sac disease affects the fry before the yolk sac is absorbed, and usually appears within 1 or 2 days after hatching. The first symptom is an enlargement of the yolk sac which soon becomes so heavy that the fish is unable to rise to the surface. When in this condition, the fry can no longer maintain an upright position and may be seen lying quietly on its side. In some cases the sac bursts after a few days, but rupture of the yolk sac appears to be the exception rather than the rule.

The enlargement of the yolk sac is due to accumulation of a serous fluid in the abdominal cavity between the inner and outer walls of the yolk sac. This fluid often has a bluish tinge which has given rise to the name commonly applied to the disease. The accumulation of fluid is frequently followed by fusion of the fat droplets of the yolk into a large, plainly visible globule. Later certain areas of the yolk become white and opaque. This condition spreads and may eventually involve the entire yolk. In many instances the affected fish continue to develop, but only the normal portion of the yolk is absorbed.

The cause of the disease is not definitely known, but has been by different authors variously ascribed to rough handling of the eggs, resulting in shocks or jars, to too much pressure during shipping, and to infection by bacteria. In support of the last-mentioned view, it has been discovered by a German investigator, L. von Betegh (1912), that the serous fluid may contain a pure culture of a diplobacillus. In this country Guberlet, Samson, and Brown (1931) found a pure culture of a diplobacillus similar to that described by von Betegh in the serous fluid of salmon fry suffering from the disease. These investigators were able to infect salmon by placing them for 5 to 30 minutes in water to which a culture of the organism had previously been added. They report that the younger fish exhibited a higher degree of susceptibility than did the older fry. According to Atkinson (1932), treatment of trout eggs with a 1 to 2,000 solution of acriflavine for 25 minutes greatly reduced subsequent loss of fry in an epidemic of the disease caused by a similar diplobacillus.

An epidemic of sac disease at the Springville (Utah) hatchery was found by K. G. Bunnel and C. N. Feast (unpublished report) to be due to a specific infection by bacteria which were identified as *Proteus hydrophilus*. Experimental inoculations with this organism gave positive results in all cases.

On the other hand, an investigation by Frederick F. Fish (unpublished report) of an outbreak of sac disease among brook- and brown-trout fry at the Leetown (W. Va.) station yielded little evidence of a specific infection. Cultures from the serous fluid gave negative results except in a few instances. Sections of the tissues of diseased fish also failed to disclose any evidence of bacterial activity. Furthermore, there was no evidence of the spreading of the disease from one trough to another, as is usually the case with bacterial infections.

Further support of the view that blue-sac may occur in the absence of a bacterial infection is supplied by Schereschewsky (1935), who holds that the dropsical condition is simply the expression of a general sickness. It is, in fact, the result of dilation of the circulatory vessels, which causes general blood congestion. In addition to the accumulation of serous fluid in the yolk sac, this investigator finds that there are marked pathological changes in other parts of the body, especially in the liver and kidneys. The primary cause of the abnormal condition of the various organs is believed by Schereschewsky to be improper functioning of the thyroid glands. In other words, blue-sac is a symptom of a goitrous condition which may appear even in the embryo.

Constriction of the yolk sac is believed by this author to be a secondary symptom of the same pathological condition. The constriction appears at the point in the yolk sac where congested veins cause accumulation of large quantities of blood, which results in the more rapid absorption of yolk in that area.

It seems probable that the term sac or blue-sac disease has been applied to any abnormal condition of the yolk sac which involves the accumulation of serous fluid. It is not improbable that lesions of this nature may at times be due to bacterial infections, while in other cases they may be the result of improper care or handling of the eggs. There is also some evidence that the mineral content of the water may in some instances be an important factor.

References: von Betegh, 1912; Leach, 1924; Guberlet, Samson, and Brown, 1931; Atkinson, 1932; Schereschewsky, 1935; Dieterich, 1939.

SOFT-EGG DISEASE

The soft-egg disease is a peculiar condition of the eggs which has caused very heavy losses at a number of commercial hatcheries in New England. The disease, which does not appear until sometime after the eggs are spawned, is characterized by a soft and flaccid condition of the eggs. The cause of this condition is the formation of minute openings in the egg membrane, which allow the water to pass freely in either direction, thus destroying the turgidity characteristic of normal eggs. If these perforations are formed before the yolk sac has developed, more or less of the yolk may escape into the water, where it immediately hardens.

The openings in the egg membrane are produced by some external agency, which in small localized areas causes disintegration or digestion of the membrane. There is no doubt that the perforations are produced by some microscopic organism, but the identity of this organism has not been definitely determined. Three types of organisms usually are found in the infected areas —a fungus (*Saprolegnia*), bacteria of several species, and an ameba. There is little doubt that the primary cause of the disintegration of the egg membrane is either bacteria or the ameba, because the fungal filaments seem not to be present until after the perforations have been formed. The filaments then grow through the holes and spread out on the inside of the egg membrane. The evidence at hand seems to indicate that the ameba is the primary agent rather than the bacteria, but this evidence is by no means conclusive.

Fortunately, exact knowledge of the source or nature of the causative organism is not necessary for working out efficient methods of control. Since the cause of the trouble is undoubtedly some organism that gets on the eggs after they are removed from the fish, it is evident that rigid sterilization and antiseptic methods are the prime requisites. All pans, and other receptacles, including trays, should be thoroughly sterilized (preferably by boiling) at frequent intervals, and all troughs should be painted each season. Every precaution should be taken to avoid, as far as possible, introduction of infection from outside ponds, and in spawning and washing the eggs, clean spring water should always be used. At a number of hatcheries very good results have been obtained by treating the eggs for a short time with a strong salt solution. Where these methods of control have been adopted the loss from soft eggs has been reduced to a negligible quantity.

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UNITED STATES DEPARTMENT OF THE INTERIOR

DENTIFYING INJURY BY WILDLIFE TO TREES AND SHRUBS IN NORTHEASTERN FORESTS

y JOHN PEARCE

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CONTENTS

Pa

Introduction

Groups of wildlife injurious to forest growth

Injury done by browsing animals

  Deer, elk, and moose

Injury done by rodents

  Beavers

  Hares and rabbits

  Meadow, red-backed, and pine mice 1

  Porcupines 1

  Gray and red squirrels 1

  Wood rats, muskrats, and woodchucks 1

Injury done by miscellaneous species of wildlife 1

  Black bears 1

  Birds 1

    Woodpeckers 1

    Starlings and herons 1

    Grouse 1

    Grossbeaks, finches, and crossbills 1

  Wildcats 2

Miscellaneous types of injury 2

  Chewing tags 2

  Gnawing around entrances to dens 2

  Gnawing stakes 2

  Flooding of trees by beavers 2

Summary 2

Bibliography 27

DENTIFYING INJURY BY WILDLIFE O TREES AND SHRUBS IN NORTHASTERN FORESTS

INTRODUCTION

Injury inflicted on trees and hrubs by mammals and birds can sually be referred to a particuar species. Animals always leave haracteristic signs, and the ability recognize these and to determine hat animal is responsible for a pecific injury is a distinct aid to hose charged with the management f forested areas. Detailed technical knowledge is not needed to make identifications, but some failiarity with the habits of wildlife cilitates the determination of inries to trees and shrubs due to eeding, breakage, or other causes. The discussion of the methods of dentification herein outlined shows ow the mammals and birds of the ortheastern States damage forsts.

Some explanation of the terms njury" and "damage" is needed efore going into details of identifiation. As herein used, the terms efer to only a part of the plant. he harm is frequently of no vital gnificance to the tree or shrub as whole. Localized injury is usally of little consequence to the lant, but even if individual trees re severely damaged, such occurrnces would have to be greatly mulplied throughout the forest to have much effect on it. Were it otherwise, herbivorous forest wildlife would soon eat itself out of food and shelter. Cases are known in which extensive damage by animals to undesirable trees actually increased the value of timber stands by reducing growth competition. Consequently, although wildlife-feeding can easily become a serious problem, it does not always follow that it is all of serious economic importance.

Frequently errors in identification of animal damage are due to the prejudice individuals sometimes have against a particular species. Identification is more trustworthy when judgment is unbiased and when personal dislikes for certain animals do not influence the classification of damage. A flagrant instance of prejudice was that which caused observers in a section in which deer had formerly inflicted severe damage to plantings to record as "deer damage" the breakage due to snow and to decay following death of the plants from winter killing and frost heaving. Inasmuch as these two types of damage were widespread throughout the plantations, the survey resulted in grossly incorrect conclusions.

GROUPS OF WILDLIFE INJURIOUS TO FOREST GROWTH

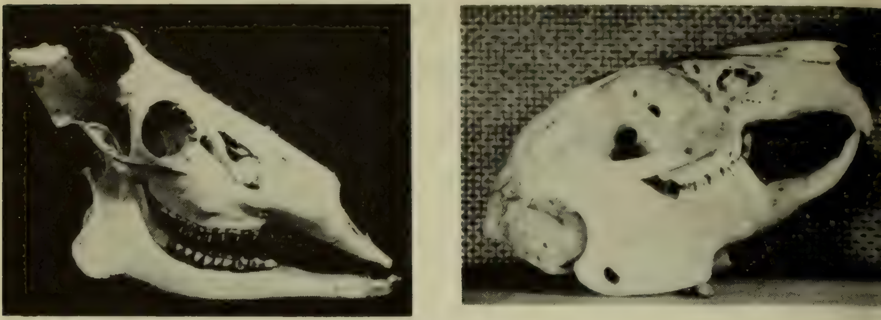

Figure 1.—Left, skull of the white-tailed deer, showing lack of upper incisors; right, skull of th snowshoe rabbit.

Besides a limited number of miscellaneous vertebrates, there are two main groups, of about equal importance, that damage woody plants in forests of the Northeast: the ungulates (hoofed animals), or browsers; and the rodents,[1] or gnawers. Potentially, members of either group may be highly destructive to young forest growth where wildlife and forest management are not coordinated. The miscellaneous species comprise birds and certain mammals that do not belong to either the ungulates or the rodents.

The wild hoofed animals of the region now include but two native species, the white-tailed deer and the moose. A species of elk, however, introduced from the West into southern New Hampshire, has now become established there. The evidence left by browsing animals in general is quite different from that left by rodents. Deer, elk, and moose all lack incisors (front teeth) in the upper jaw (fig. 1). Consequently, their manner of feeding is to pull woody stems from the plant by holding them firmly against th upper jaw and breaking them ove the sharp-edged lower incisor Since woody growth is always mo or less fibrous, this method of fee ing leaves a rough end, as shown i figure 2.

The rodents, together with th lagomorphs, of the Northeast i clude the beaver, porcupine, sno shoe hare, two species of cottonta rabbits, and several species of squi rels and mice. Their front teet differ entirely from those of brow ing animals. Rodents have tw sharp, functional, incisors in bot the upper and the lower jaws (fi 1). These are specially adapted f cutting; hence rodents, instead breaking tough food, cut it o Most species leave a fairly smoot more or less slanting end (fig. after cutting.

This is because the animal hold its head at an angle, possibly fin ing it easier to cut across the grai on a slant. Characteristic toot marks are usually imprinted on gouged out of the wood or bark du ing the cutting.

The miscellaneous group consis mainly of birds, including the ye low-bellied sapsucker and oth

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[1] For convenience, the term "rodents" as here used includes (1) the true rodents and (2) the lagomorphs, or rabbits and hares.

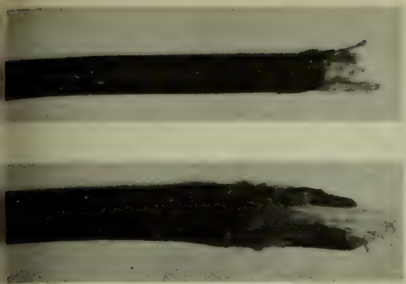

Figure 2.—Twigs browsed by deer.

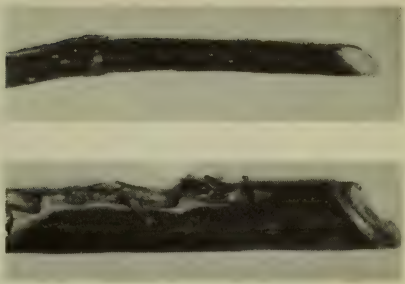

Figure 3.—Twigs gnawed off by a cottontail rabbit.

woodpeckers, the ruffed and spruce grouse, grosbeaks, and the starling, although bears, wildcats, and woodchucks may cause occasional injury.

Domestic animals, especially cattle, horses, sheep, and goats, may inflict injury to trees and shrubs in some localities. Branches cropped by these animals are indistinguishable in appearance from those browsed by wildlife, so care must be taken to make allowances in places where domestic animals may be responsible. One outstanding difference between deer and cattle browsing is the more methodical and sweeping destruction by cattle. Ordinarily deer do not strip a plant of most of its browse on the first or second visits, unless the supply is exceedingly scanty. Their nervous behavior while feeding tends to keep them moving. Cattle, on the contrary, show a decided tendency to feed more systematically, taking much more of what is readily available. Moreover, deer, being much smaller, may feed over a spot several times and cause little damage by trampling, but cattle soon break down many small trees and shrubs.

General aids for use in identifying animals belonging to one of the three groups that damage woody plants in northeastern forests include a knowledge of the normal place of feeding by the different species, of the parts of plants commonly injured, and of the height above ground at which the different animals usually feed. Such knowledge may best be gained by personal observations. Knowing what animals are found in any particular section is also a distinct advantage, especially when making a determination by the process of elimination. A hand lens may prove useful on occasion but is rarely a necessity.

INJURY DONE BY BROWSING ANIMALS

DEER, ELK, AND MOOSE

The white-tailed deer (*Odocoi-eus virginianus*) is the only member of the browsing group found throughout the Northeast. Except in parts of Maine and except for occasional stragglers in Vermont, Massachusetts, and New Hampshire, there are no moose (*Alces americana*) in the forests of the region at the present time, and the introduced wild elk (*Cervus*) are restricted to southwestern New Hampshire. During the last decade deer have become an important problem in many localities, chiefly because of their adaptability to the numerous abandoned agricultural lands and cut-over areas of the region. Zealous protection in some places, together with lack of realization that overpopulation results in serious damage to the range, has emphasized the necessity of recognizing deer damage in the field. Incipient danger will be revealed by the state of the vegetation if browsing signs are thoroughly understood.

There is no appreciable difference in the appearance of twigs browsed by deer, moose, or elk other than in the size of the largest branches that each can break off conveniently. Woody stems remaining after browsing by any of these animals are rough, more or less shredded, and approximately square across. The height to which the animals feed varies with the species, but i also varies within a species. Unde starvation conditions caused b severe winter weather, all three animals will reach higher for food b standing on their hind legs, and wil also feed upon coarser, thicke branches than normally. Northeastern deer rarely browse highe than 6 feet from the standing level but under stress they are able t reach 8 feet or somewhat more. Instances of elk and moose browsin much higher, nearly to 11 feet in th case of moose, have been observed All three animals will "ride down small limber trees to feed on th tops. They do this by straddlin the trunk with their front legs an pushing against it with their chest as they step along toward the to branches. After such feeding th tree may straighten up again an will have a browsed top considerably higher than the animals coul reach in any other way.

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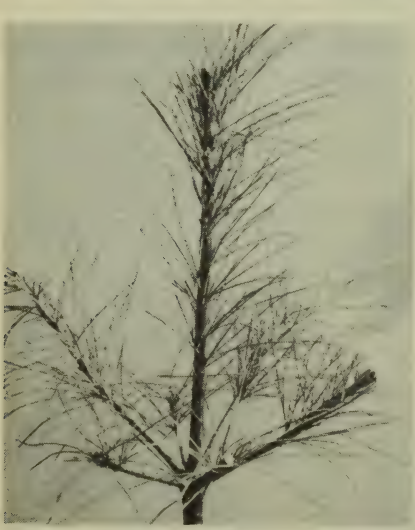
Figure 4.—White pine tips browsed by deer.



Deer apparently have trouble i browsing branches larger than hal an inch in diameter; usually the feed on much smaller branches Moose, on the other hand, can manage stems more than an inch i diameter, and elk those nearly a large. Prolonged feeding on larg branches, however, causes mout disorders in all three species, and regular feeding on such larg branches indicates extreme scarcit of food. An observer familiar wit the feeding habits of these animal can distinguish a deer-yarding are from a moose yard at a glance. Th latter reveals the eating of coarse twigs and the breaking off of a considerable number of uneate branches. Extensive feeding o

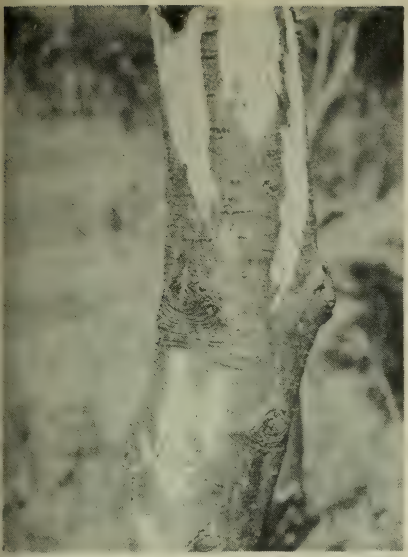


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Figure 5.—Tree trunk showing effects of elk feeding on the young bark. Note the broad gouges made by the incisor teeth.

the larger sizes is a sign of overbrowsing in yards of both animals.

Browsing on trees is not confined to the branches and principal stems. Deer, particularly, are capable of rather dainty feeding and may nip only buds with a smaller part of the stem. On slow-growing branches these buds are often very small. The broken end of the stem and the slenderness of the limb, together with its height from the ground, usually serve to eliminate other mammals. This kind of feeding sometimes resembles budding by grouse. Grouse, however, ordinarily stand on the ground or on another limb to do their budding; the small buds referred to as being eaten by deer rarely prove attractive enough to make the birds jump up from the ground as they will do at times to feed on highly palatable fruit just out of reach. Bud-browsing by deer on the longer-needled pines results in a nearly square cropping of the end needles surrounding the bud (fig. 4). This type of feeding is common on forest plantations.

Bark-peeling is done by all the browsing group, and although much less frequent than twig-cropping, it is more destructive. Most frequently the browsing animal peels the bark by scraping a piece loose with its front teeth until it obtains a firm hold, and then pulling the strip, usually upward, from the trunk until it breaks. The strip often tapers to a narrow point before breaking and may extend considerably beyond the reach of the animal. Sometimes the tooth marks are found impressed on the exposed trunk or in the inner bark, those made by the moose or the elk being rounded, rather shallow grooves (fig. 5), and those by the deer, smaller, narrower, and less indented. Neither spines nor thorns are effective deterrents in preventing twig-browsing or bark-peeling. Devilsclub (*Aralia spinosa*), an exceedingly well-armed shrub, is regularly peeled by deer in some sections, and winter feeding on hawthorn (*Crataegus*), greenbriers (*Smilax*), and the canes of the blackberry (*Rubus*) is also common.

The shape of the different trees and shrubs after being regularly browsed upon varies with the species. Young balsam fir (*Abies balsamea*) may be reduced to a single clublike stem with extra long, vigorous needles growing from it. Other species may become hedgelike, or "boxed," in appearance, particularly the hemlock (*Tsuga canadensis*) and the mountain holly (*Nemopanthus mucronatus*). This

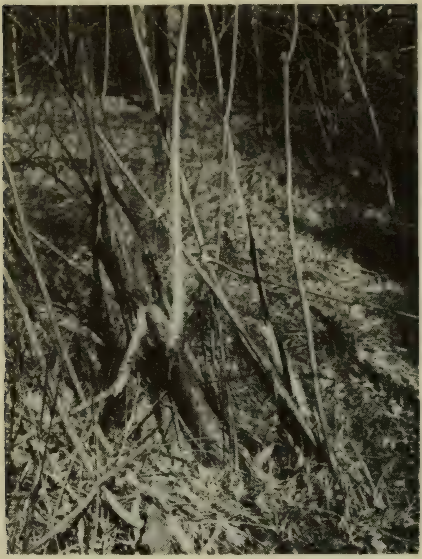

Figure 6.—Sapling used by deer for polishing antlers. The finely shredded bark is characteristic. (Photograph by the United States Forest Service.)

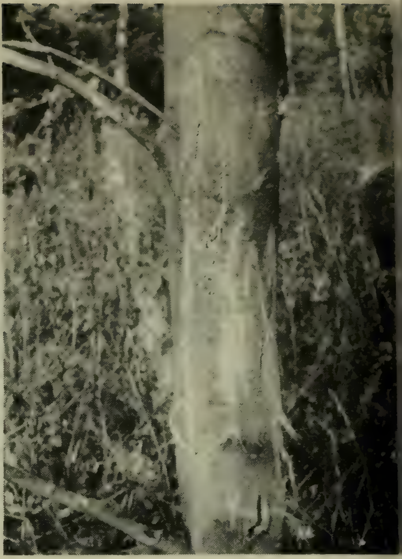

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Figure 7.—Trunk of tree showing scorin made by elk in rubbing the antle against it.

compact appearance of the hemlock, however, may also be due to the tree growing in a "frost pocket" where cold air collects from surrounding areas and kills back tender young shoots year after year. Judgment should not be passed until close inspection is made. Frost may kill back all the tips uniformly without breaking the ends of the stems. Old dried shoots that have been frostbitten break easily after a time, leaving an end resembling that resulting from deer-feeding. As a rule, such a break can be seen at a glance to be much more recent than the dying of the branch. Since deer do not browse dead twigs, they can be eliminated from consideration in such cases. A single light browsing on hobblebush (*Viburnum alnifolium*) produces excessively long lateral branches from the remaining two top buds, but heavy, perennial browsing of the same plan reduces it to low, dense patches.

Deer, elk, and moose frequentl select small trees on which to ru and polish the velvet from thei antlers late in summer and early i fall. Deer, in most instances, choos saplings about an inch or less i diameter. Hardwoods of som strength, as maple, willow, an birch, seem to be preferred, but thi is not a constant rule, as large trunks, conifers, stumps, and boulders may be used at times. Elk an moose more often choose trees several inches in diameter. Deer leav the bark on these trees in a rathe finely shredded condition. Thi practice can be distinguished fro bark-peeling for browse by the long frayed shreds of bark left hangin (fig. 6) from the top and botto of the bark wound, and by the ab sence of tooth marks. The elk and the moose often rub the trunk almost bare, leaving few shreds of bark. They also break more branches. Blunt, erratic gouges scored by antler points are much more commonly seen on rubbing-trees of elk and moose (fig. 7) where only a little work has been done. These marks may be found several feet up from the ground. Deer-rubbing is confined mostly to the section of the trunk between 1½ and 3½ feet above the ground.

INJURY DONE BY RODENTS

Injury to trees and shrubs caused by the feeding of rodents upon them, with the exception of one or two instances discussed later, can be recognized by the characteristic gnawing marks made with the front teeth. Which species of rodent is responsible for a particular injury can be determined mainly by the grooved gnawing marks. Table 1 shows the average widths of the incisors of the rodents of northeastern forests and the average widths of the grooves they leave on wood. The figures for the grooves are from winter gnawings and represent cutting by either adult or subadult animals. It might seem that the gnawing of a large snowshoe hare could be confused with that of a small porcupine, but actually this is not likely, because the usual season of feeding on woody growth is after cold weather begins, at which time young animals are well grown. Like the browsing of ruminants, the gnawing by rodents, with the exception of that of beavers which ordinarily do the bulk of their cutting late in summer and in fall, is more in evidence during the winter. Even the porcupine eats much less bark in summer than it is popularly supposed to do; it prefers more succulent herbaceous food at that season.

Table 1.—*Average widths of the incisor teeth and of tooth marks of important rodents in the forests of the Northeast*

Rodent	Average width of incisors	Average width of tooth marks
	Inch	*Inch*
Beaver (*Castor canadensis* subspp.)	0. 24	0. 20
Porcupine (*Erethizon dorsatum*)	. 14	. 10
Rabbit, cottontail (*Sylvilagus floridanus* subspp. and *S. transitionalis*)	[1]. 10	. 08
Mouse, meadow (*Microtus pennsylvanicus* subspp.), and mouse, pine (*Pitymys pinetorum*)	[2]. 06	. 04
Squirrel, gray (*Sciurus carolinensis*), and squirrel, red (*Tamiasciurus hudsonicus* subspp.)	. 03	. 01

[1] Measurements for the snowshoe hare are a trifle larger than those for the cottontail rabbit.

[2] Measurements for the pine mouse, though somewhat smaller, follow very closely those of the meadow mouse.

BEAVERS

The conical stumps of beaver-felled trees (fig. 8) are easily distinguished. The pronounced channels (fig. 9) gouged out by the larger incisor teeth of the beaver also are unmistakable. Only that animal consistently gnaws through trunks and large branches. Occasionally beavers will pull small strips of bark from hemlock, pine, or spruce, but usually leave the print of their teeth on the trunk. Figure 10 illustrates a type of split cut left by both the beaver and the porcupine.

One beaver sign that sometimes proves puzzling consists of bare twigs that remain after the beavers have peeled the bark from branches too small to show tooth marks. Beavers are more adept at this kind of feeding than are rabbits or hares. The branches may be so small and so neatly peeled as to make the work appear impossible to be that of the clumsy-looking beaver. This animal can peel a water-soaked aspen twig one-eighth inch in diameter without leaving a mark on the soft wood. The other rodents cannot do this without leaving telltale marks. Such twigs may float downstream or along lake shores long distances from where they were peeled.

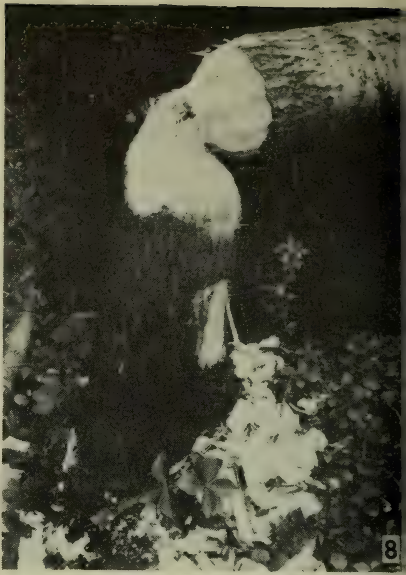
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Figure 8.—Tree gnawed by beavers, showing the conical stump usually left by these animals.

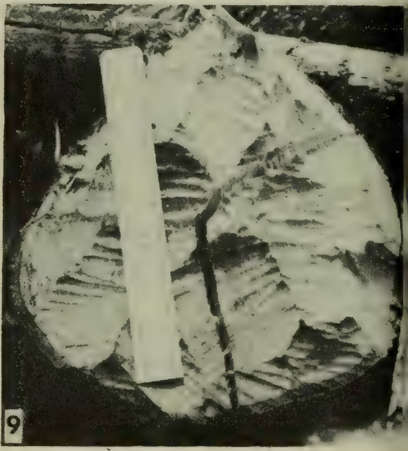
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Figure 9.—End view of stump cut by beavers, showing the pronounced channels gouged out by the large incisor teeth.

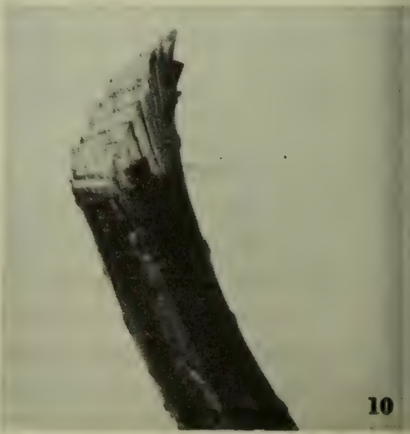
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Figure 10.—Branch, placed under stress by bending, gnawed by beaver, showing the split end.

Because of the similarity of their feeding habits, the snowshoe hare (*Lepus americana*) and the cottontail rabbit (*Sylvilagus*) are discussed together. As with most other rodents, these animals normally attack woody growth extensively only in the absence of more succulent vegetation. In winter they feed on the bark of young trees and branches, twigs, lopped-off tops, and new brush piles. They seldom reach higher than 18 inches above the ground or snow level. Under stress of extreme hunger they may gnaw the bark from brush cut months before.

Many species of trees and shrubs may be "barked." In general, snowshoe hares show a much stronger liking for coniferous bark than do cottontail rabbits. The bark of the trunk of a young tree may be gnawed off over relatively large patches, but that of smaller branches seems to be preferred. Bark-gnawing by hares and rabbits varies greatly in appearance. Soft twigs, those with pithy centers or those with thin bark that peels easily, are left with a very ragged appearance (fig. 11), more so than bark gnawed by the true rodents of the region. The gnawed twig of a species having hard wood and thicker bark has a noticeably neater appearance.

A second type of gnawing by rabbits and hares is also recognized—the clipping of small edible branches. End growth that has been clipped by rabbits can be distinguished by the clean, slanting cut, and the resulting tooth marks. Beavers, leaving no trace of tooth marks, will sever with one snip branches of the size customarily chosen by rabbits. The usual cut made by a rabbit closely resembles a 45° cut made with a knife, as shown in figure 3 (p. 3). The teeth leave a much narrower groove than those of either the porcupine or the beaver. Small, slow-growing conifers that have been heavily pruned by rabbits have an umbrella-like appearance when the lower branches have been trimmed and the upper ones are out of reach. Clipping also results in another type of damage, which may be rather striking. When the hare or rabbit feeds in dense patches of seedlings and consumes nearly the whole stem of the plant, a roughly circular patch may be cleared if the

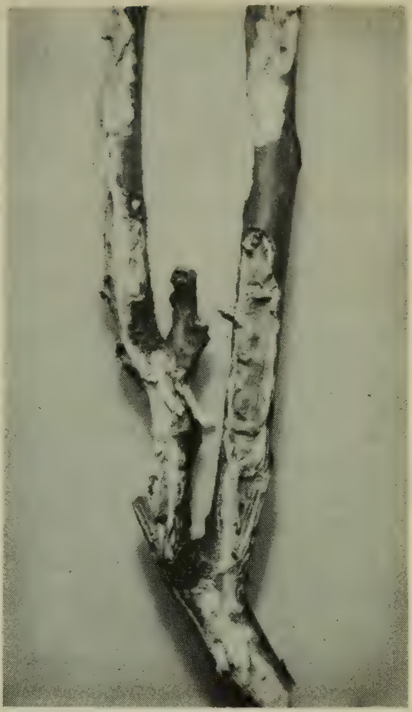


Figure 11.—Twig of sumac (*Rhus*), a pithy shrub, that has been gnawed by a cottontail rabbit.

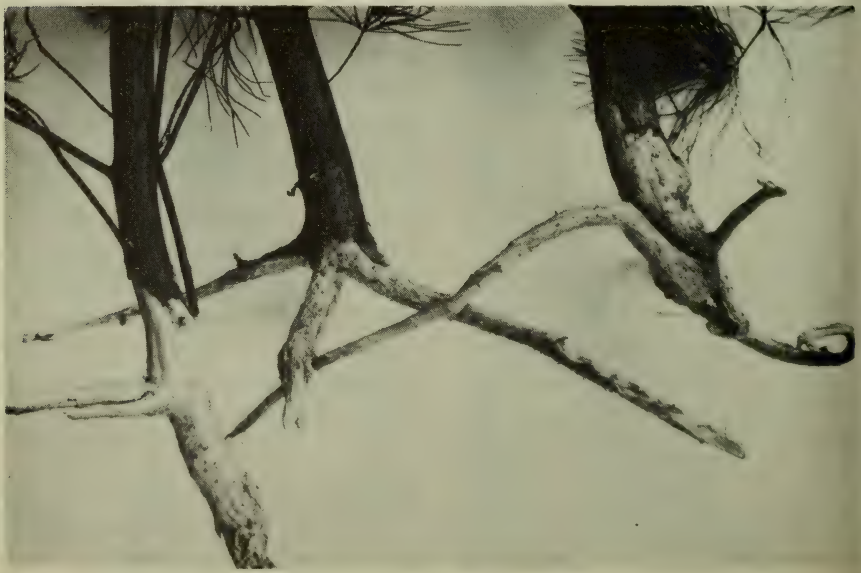
animal is not disturbed. These patches are characterized by their small size, being seldom more than a foot across, and by the uniformit of the height of the stubs (usuall 3 to 4 inches).

MEADOW, RED-BACKED, AND PINE MICE

Meadow, red-backed, and pine mice are grouped together because their work is practically identical. These three groups are responsible for nearly all the mouse damage to trees and shrubs. Ordinarily these mice feed on trees and shrubs only in winter, but they may attack green-barked young trees even in summer. Other groups of mice either hibernate in cold weather or feed chiefly on stored-up seeds.

The familiar meadow mouse (*Microtus*), frequently referred to as the meadow mole or vole, scarcely needs describing. Its chunky shape, short tail, and coarse, gray-black fur distinguish it from the common mouse of the woods properly known as the deer mouse (*Peromyscus*), and from the less common, long tailed, jumping mice (*Napaeozapu* and *Zapus*). The pine mous (*Pitymys*) and the red-backe mouse (*Clethrionomys*) are les widely distributed and are les likely to be seen than *Microtus* The pine mouse is decidedly smalle and has a much shorter tail (les than 1 inch long), small eyes, an fine, almost molelike, fur with a delicate brown wash over it. The red backed mouse is midway betwee the pine mouse and the meado mouse in size and texture of fur, bu its tail is about the size of that o the meadow mouse, and its back ha a pronounced streak of reddis hairs. It is distinctly a woodlan animal, preferring heavy fores

Figure 12.—Typical pine mouse damage, showing the decided tendency to girdle below rathe than above the root collar.



with a moist, humus floor, or damp weedy spots in the woods. The meadow mouse inhabits fields and meadows but is found sometimes in small glades or grassy swales, sphagnum bogs, and wet areas deep in the woods isolated from other stretches of similar habitat. These detached areas are usually connected by a stream with more extensive areas of typical habitat. The pine mouse frequents fairly light, sandy soils, and is less dependent upon the cover of grasses, sedges, and weeds than is *Microtus*. It is not, however, restricted to pine forests.

One other genus of this mouse (microtine) group may occasionally occur—the lemming mouse (*Synaptomys*). The lemming mouse is rarely seen, but may at times be fairly common over restricted areas. It much resembles the meadow mouse, but has a short tail like that of the pine mouse. This genus is further characterized by a longitudinal groove in each upper incisor tooth.

Microtus damage does not usually extend into bare openings, but generally occurs under cover of snow or matted vegetation. These mice usually gnaw the bark from small trees near the root collar and up the trunk as high as protective snow cover extends. They may fell small trees or shoots up to about one-fourth inch in diameter, leaving stumps like miniature beaver work. Little piles of twigs 3 to 4 inches long, denuded of their bark, are frequently made by these mice during protracted feeding on such growth. Occasionally roots are stripped of their bark by meadow mice, but this damage is primarily the work of pine mice, which spend far more time below ground than do their larger relatives. Whereas the presence of meadow mice is often revealed by numerous burrows traceable on the surface, pine mice with their underground burrows may do extensive root damage unnoticed, and the condition of the tree may not be detected until spring or even later.

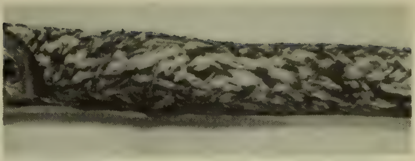


Figure 13.—Stem gnawed by meadow mice.

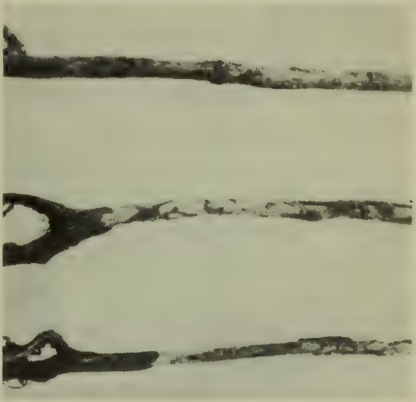


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Figure 14.—White pine seedlings girdled by Pale's weevil (*Hylobius pales*).

Pine mice are more often pests of orchards than of forest plantations. At times their presence may be discovered by pulling away the mulch grass and debris from the base of the trunk and exposing their runways, or the burrows can be detected by probing the ground close to trees on which the mice may be working.

When the damaged roots are examined, it will be found that large irregular patches of bark have been gnawed off, mostly from the root collar and the under side of the larger roots (fig. 12). The denuding may be extended over several winters, the tree becoming progressively less vigorous. The lack of vigor is indicated by off-colored foliage, early shedding of leaves, smaller winter buds, and shorter branch growth.

Gnawing by mice is less uniform in direction (fig. 13) than that by other rodents. Tooth marks will be found running at all angles even on small branches. Ordinarily the marks vary from light scratches to channels 1/8 inch wide, 1/16 inch or more deep, and 3/8 inch long. In proportion to size, the incision from each bite is noticeably deeper than that made by rabbits or squirrels

A type of insect damage con monly found on young white pir seedlings in some sections of tl Northeast is sometimes erroneousl attributed to mice. This is the dan age caused by the feeding of Pale weevil (*Hylobius pales*) (fig. 14 The bark is removed in tiny rounde bites, the individual bite marks c which may be discerned on carefu examination. The paired toot cuts of mice, however, cannot b found, and the tiny strips of bar between the grooves often left b mice are also absent. These strip are formed because of the sligh divergence and narrowing of the incisors of the mice at the tips, whicl leave a small opening in the scrapin edge.

PORCUPINES

The feeding of the porcupine (*Erethizon*) is mainly destructive to the bark of trees (fig. 15). Olde bark is taken as well as tender barl like that chosen by rabbits and mice Second in importance is the damage caused by twig pruning, or clipping, which is most frequently noticed in hemlocks used by the porcupines for rest trees. Many othe trees also are trimmed, sometime in the efforts of the animals to ge at the acorns or other fruit on th ends of small branches. Usuall the area where the bark has beer removed is of such extent and sc located on the trunk or large branches as to identify the damage immediately as that caused by porcupines. Even in localities in which other animals might be responsible the characteristic tooth marks o the porcupine, larger and better defined than those of squirrels, rabbits, or mice, but narrower than

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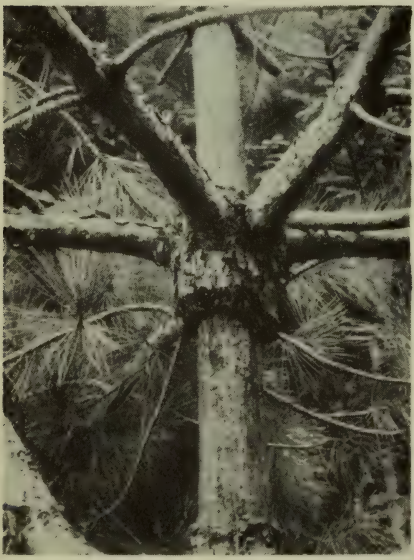
Figure 15.—Young red pine (*Pinus resinosa*) which grew 5 years after being girdled by a porcupine.



those of beavers, are readily discernible. The bark may be completely removed from slender twigs that seem inaccessible to the cumbersome-looking porcupine. In its slow, cautious way, however, the "porky" is expert at stripping small branches while clinging to seemingly unstable support. The gnawing of the porcupine to remove twigs and small branches may leave ends like those shown in figure 16, or the slanting end may be split into several parts, as in cuttings made by beaver (fig. 10, p. 8). It is not always apparent why branches are clipped off by porcupines as they are not always used for food. A sort of crude platform is sometimes left of cut-off twigs ¼ to ¾ inch in diameter, usually at a small crotch in the crown. This platform will measure about 1 foot across.

Injury due to white pine blister rust is sometimes attributed to the porcupine, as patches of wood exposed where the diseased bark has fallen off at the place of an old "blister" superficially resemble the denuded areas left by that animal. Porcupine tooth marks are absent, however, and the shredded bark around the edges of the old blister tends to become rough and frayed and no callus is formed. Porcupines, on the other hand, usually leave edges around which a fast-growing callus forms. There is a condition brought about by the chewing of fresh blister-rust cankers by red squirrels that may resemble porcupine damage. As squirrels have very narrow incisors that taper to points even finer than those of meadow mice, however, their small tooth marks should never be mistaken for those of porcupines.

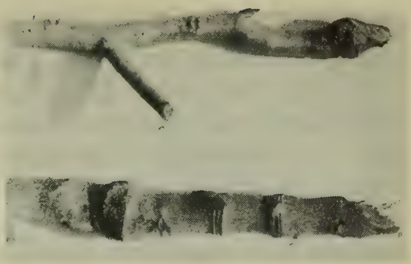

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Figure 16.—Aspen branches pruned by the porcupine.

Dead trees partially denuded of bark should be examined carefully for evidence of insect depredations. The presence on the surface of the wood of undamaged galleries of larval bark beetles, for instance, may prove that the denuding is due to them rather than to porcupines.

Although porcupine feeding on trees is restricted almost entirely to the bark, the wood beneath not being eaten, subsequent growth on girdled trees (fig. 15) may make it appear that wood has been removed. Many odd growths may be formed by winding "bridges" left across areas otherwise gnawed clean. Porcupine tooth marks may remain visible on bare wood for years; those shown in figure 15, though on relatively soft wood, were 5 years old.

GRAY AND RED SQUIRRELS

The gray squirrel (*Sciurus carolinensis*) and the red squirrel (*Tamiasciurus hudsonicus*) attack woody growth in essentially the same manner and cause several types of injury. The clipping of nuts, acorns, and pine cones is a familiar example, but less widely understood is the pruning of twigs for buds and flowers or fruits. This practice by red squirrels to obtain winter buds of spruce, pine, and larch is especially noteworthy. Bark is sometimes gnawed from trees for use as food in times of stress, particularly by red squirrels. They may gnaw the bark of sugar maples early in the spring when the sap is running, apparently to drink the sap. In such instances, they make a roughly circular, untidy-appearing hole in the bark, leaving the usual rough edges characteristic of these animals. Gnawings are frequently found on white pine blister-rust cankers, which, as previously mentioned, are sometimes mistaken for porcupine work.

Gray squirrels sometimes strip off bark for use in nests. This normally occurs on limbs already dead, and it is the inner bark that is usually sought. In the West, it is reported that during poor seed years or early in spring when other food is scarce, gray squirrels may strip the bark from the tops of conifers to feed on the attached cambium.

Tip-pruning is perhaps the most serious type of damage done by the squirrels, because the trees chosen frequently are planted conifers. To all appearances, the more vigorously growing trees with larger bud are preferred. Injury here is o two kinds: one in which the bud scales are simply chewed away in place or after the leader has been gnawed off, and the other in which only two or three basal bud scales are removed. Sometimes observers find it difficult to believe that squirrels could be responsible for twig pruning of this type, especially pruning of the slender, upright terminal shoots of white spruce (*Picea glauca*) that frequently do not look stout enough to support a red squirrel. Allowance should be made in such cases not only for the agility of the animals but for the fact that such damage is usually done in cold weather when the stem is more rigid than at other times. Examination of the rifled buds, either in place or on pruned off branches, may also prove mystifying, for squirrels are able to remove the contents of the larger spruce buds without disturbing more than a few bud scales, leaving a hollow shell of scales intact. This is probably no more difficult for these animals than extracting nut meats from intricate shell crevices, a task for which their long pointed teeth and the narrow clawed digits of their fore paws are well adapted. At times confusion results from the easily gained impression that only birds could alight on such small branches and remove the buds or break off the twigs; yet in most cases the branches are too stout for any of our native bud-eating birds to break. This type of squirrel feeding is frequently associated

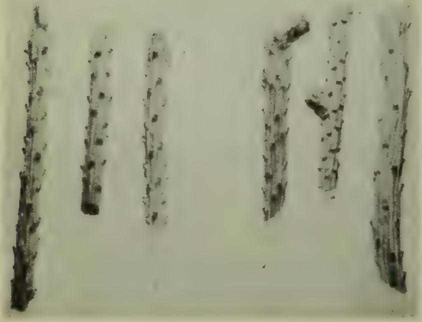
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Figure 17.—White spruce tips chewed by red squirrels.

with a sudden heavy snowfall late in winter or early in spring after a prolonged thaw or an open winter has caused the squirrels to become unusually active. Unable to forage on the ground for food at a time when other food is scarce, red squirrels during such periods will travel a quarter of a mile or more from thickets of old, slow-growing conifers to feed on young plantations.

The severing of twigs by squirrels, as shown in figure 17 is not very clean. On conifer branches the cut often appears smoother and more nearly square across than it actually is owing to the exuded resin. This is the one rodent cutting that superficially resembles deer browsing. Resin often flows copiously from these cuttings, and when the exudation dries, it covers up the rough end making it appear to be a fairly smooth, square break. If the caked gum is removed, evidence of the typical slanting cut of a rodent is usually found.

Close examination of the teeth of a squirrel reveals them to be less adapted to gouging out chips of wood than are those of other forest rodents of the region. Its incisors are slightly triangular in cross-section near the point and are flattened at right angles to the plane in which the incisors of the other rodents are flattened; consequently the tooth surface used in gnawing produces more of a scratching or rasping effect than a gouging out of chips.

WOOD RATS, MUSKRATS, AND WOODCHUCKS

In restricted areas in eastern and southern New York, western Connecticut, and western Massachusetts, the effects of the feeding of the wood rat (*Neotoma*) on bark may be observed occasionally late in winter or early in spring. Small irregular pieces are chewed from young bark. The tooth marks may be puzzling as they are intermediate in size between those of the squirrel and those of the rabbit, yet the feeding spots are something like those of squirrels. At a casual glance such gnawed spots may even appear to be the work of the porcupine and they may be found in small trees. The wood rat is rare over most of the northeastern region and due caution should be used in attributing damage to it, particularly since its normal feeding habits do not include much feeding on bark.

The gnawing of bark by the muskrat or the woodchuck occurs but rarely and over a more widespread area. The only instances of bark-gnawing by muskrats seen by the author were on green willow shoots. The shoots were very clumsily cut off; they did not have the characteristic slanting rodent cut; and very rough ends were left. The location of such work is ordinarily a clue to identification. The woodchuck gnaws on small stems and the trunks of saplings at times in early spring, or even later in the season. Why this is done is not clear. Such gnawing is usually near the dens of the woodchucks and, like the work of the muskrat, is not a neat job, the bark ordinarily being erratically chewed and ragged in appearance. Where a good clean tooth mark can be seen, it is approximately the size of that of a rabbit, but these are seldo found.

INJURY DONE BY MISCELLANEOUS SPECIES OF WILDLIFE

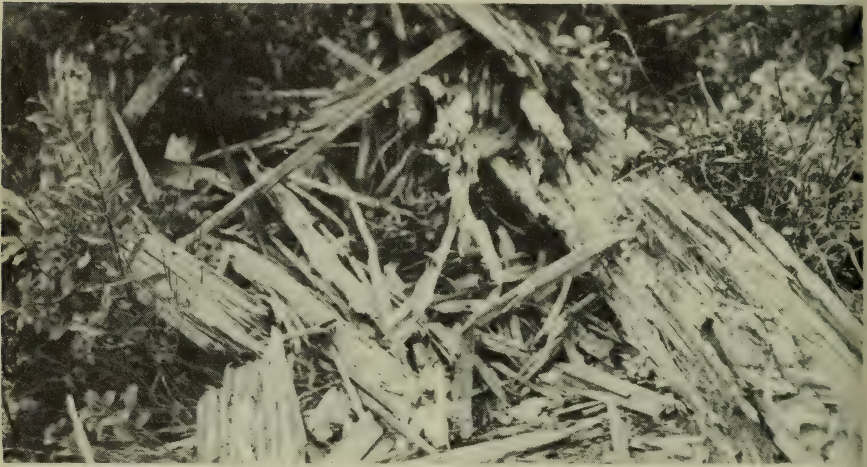

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Figure 18.—A log torn apart by a black bear in search of ant larvae.

BLACK BEARS

The feeding by bears (*Euarctos americanus*) on food-bearing trees and shrubs is likely to be very destructive to the plants. The weight and strength of these animals cause severe breakage of apple (*Malus*), black cherry (*Prunus serotina*), shadbush (*Amelanchier*), and similar trees. The damage to blueberry (*Vaccinium*), raspberry (*Rubus*), blackberry (*Rubus*), and the like is of less consequence because it is more rapidly repaired. Generally, the nature of the break and the strength or weight required to accomplish it make it obvious that only a bear could be responsible. The deep, blunt tooth marks and heavy claw scratches in the wood are also guiding signs of bear damage.

Claw marks alone are sometime the only guide, as on "bear trees," where passing bears leave thei marks. Bears traveling by subsequently also stand up to mark th trees with their claws. An interesting sight familiar to most woodsmen is the sign sometimes found o large beeches where a bear ha climbed up years before. As th tree trunk expands in size, the cla marks become wider apart. The result is a series of huge sets of cla marks.

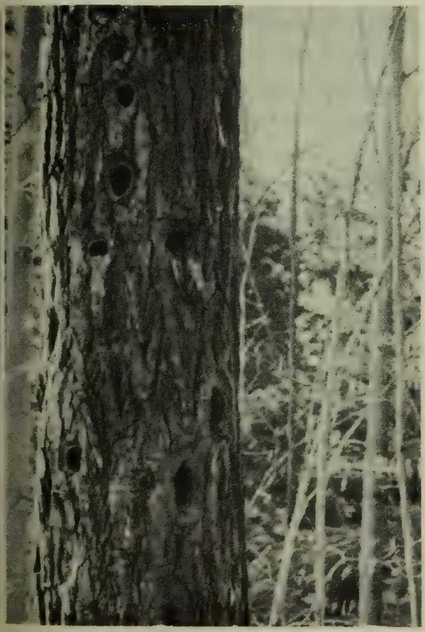
On rare occasions bears claw ou holes in living tree trunks in excavating honeycomb or colonies o ants. Among our native fauna, onl the bear has the great strength i its claws required to do this. Mor common locations of similar wor are dead trees and, where ant larvae are sought, stumps and fallen logs. The splintered edges of the hole and the slivers of wood lying on the ground (fig. 18) are always associated with this type of bear work.

BIRDS—WOODPECKERS

So far as their direct injury to the trees of the Northeast is concerned, the woodpeckers fall into three groups: The shallow diggers, the deep excavators, and the sapsuckers.

The first group, which does very little damage, rarely excavating live wood, comprises the flicker (*Colaptes auratus*), the uncommon (in the Northeast) red-headed woodpecker (*Melanerpes erythrocephalus*), the hairy woodpecker (*Dryobates villosus*), and the downy woodpecker (*Dryobates pubescens*). The flicker and the red-headed woodpecker are chiefly ground feeders and usually make their nests in dead stubs. While both the hairy woodpecker and the downy woodpecker dig extensively for bark-inhabiting insects, the latter species at least prefers dead trunks and branches for its nest. There are a few records of the two last-mentioned woodpeckers removing irregular patches of bark seemingly for the cambium, but this habit is limited.

Figure 19.—Woodpecker excavations in various stages of healing.



The second group includes the woodpeckers that habitually excavate deeply for wood borers, and is one that has caused considerable controversy because of the holes made in live wood by the birds in search of grubs. Although these woodpeckers in extracting borers may possibly do more damage to lumber than would the borers in the tree at the time, it is curtailment of succeeding generations of destructive borers that determines the real value of the birds. Moreover, because of the low value of borer-damaged timbers, it is a moot question whether logs from trees in which the grubs are numerous enough for the woodpeckers to do extensive work are worth processing into lumber. The excavating species in the Northeast are the pileated woodpecker (*Ceophloeus pileatus*), the Arctic three-toed woodpecker (*Picoides arcticus*), and the American three-toed wood-

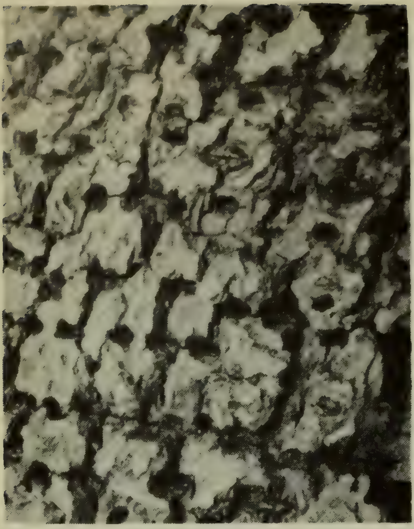


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Figure 20.—Bark of tree drilled by sapsuckers.

pecker (*Picoides tridactylus bacatus*). The rough excavations made by these three birds are not likely to be confused with any other kind of damage. The holes, except the cylindrical nest entrances, are usually oblong in outline, with the long side running with the grain of the wood (fig. 19). The somewhat similar holes occasionally made by bears are much more irregular in outline and are characterized by splinters rather than by the chips made by the woodpeckers. Woodpecker cavities may be made in the same tree over a period of many years. The large cavities made by the big pileated woodpecker are very striking and may be 2 feet or more long, 1 foot deep, and 1 foo wide. The smaller, three-toed woodpeckers make cavities that rarely exceed the average size o those made by the pileated. Chips made by the pileated are larger than those found at workings of the two smaller species. This difference has little diagnostic value, however, until the observer is thoroughly familiar with the work of all three kinds, each of which makes fine, as well as larger chips. There does not appear to be any constant sign that definitely distinguishes the work of any one of these woodpeckers.

The third group of woodpeckers includes in the Northeast only one species, the yellow-bellied sapsucker (*Sphyrapicus varius*). Sapsuckers do unique damage, which so far has not been found to have any mitigating benefits. Their roundish feeding holes, arranged in more or less horizontal rows around the tree trunk (fig. 20), are a familiar sight in the northern forests. Trees of wide variety are drilled by this bird. Although the injury is not devastating to forest growth, it undoubtedly reduces the vitality of the trees, decreases their growth rate, renders them more susceptible to fungous attacks, and produces defects in the wood. Sometimes it kills branches or even entire trees.

STARLINGS AND HERONS

The starlings and the herons are treated herein as a group because the kind of injury inflicted is similar, resulting from the use of a restricted number of trees by the starlings for roosting and by the herons for nesting. In most cases both birds choose dense coniferous growths. The damage is caused principally by deleterious forms of ammonia in the birds' excreta. As he excreta fall to the ground and each into the soil, the ammonia is absorbed by the tree roots and eventually kills the trees by defoliation. There seems also to be some harmful effect from the same source directly upon the foliage. Extreme harm, however, results only from heavy and prolonged use of relatively small areas for nesting and roosting. Only two northeastern species of herons, the great blue heron (*Ardea herodias*) and the black-crowned night heron (*Nycticorax nycticorax*), so concentrate in trees at nesting time as to cause the effects described.

Furthermore, the generally unwanted starling (*Sturnus vulgaris*) is one of the few species of birds now able to inflict a type of injury that was much more common in earlier days when wildlife was still abundant, namely, breakage due to large numbers of birds overloading limbs. Passenger pigeons are recorded as having done heavy damage of this sort.

GROUSE

Two species of grouse, the ruffed grouse (*Bonasa umbellus*) and the spruce grouse (*Canachites canadensis*), are found in the Northeast. Both these birds feed extensively on buds and small twigs in the fall, winter, and spring. The ruffed grouse has a special liking for birch and apple twigs and buds, and the spruce grouse, now restricted to northern Maine, New Hampshire, and Vermont, prefers balsam and spruce buds. The feeding habits of both, however, are such that they seldom single out a particular tree year after year and so cripple its growth. Branches frequently show selective feeding on the buds alone, there being, as a rule, very little disturbance at the break. An exception is the breaking off by the grouse of the ends of tough slender twigs, leaving hanging fibers of bark at the break.

GROSBEAKS, FINCHES, AND CROSSBILLS

Pine grosbeaks (*Pinicola enucleator*), evening grosbeaks (*Hesperiphona vespertina*), purple finches (*Carpodacus purpureus*), and crossbills (*Loxia*) all feed to some extent on tree buds. The grosbeaks are capable of biting off small branches, but ordinarily limit their attacks to the buds. Pine grosbeaks generally prefer coniferous species, and evening grosbeaks most frequently choose such hardwoods as maple (*Acer*) and mountain-ash (*Sorbus*). These birds feed during the day in contrast to red squirrels which do much of their feeding at night. The typical feeding signs of the squirrels are ample enough to avoid confusing their work.

Several factors combine to make the work of birds rather unnoticeable in the forest. When many buds are missing from branches and there is no sign of twig gnawing by squirrels or breaking off by grouse, feeding by the grosbeaks, finches, or crossbills is indicated, but it must be remembered that grouse also frequently bud limbs without eating any twigs. Grouse, however, eat the entire bud, while grosbeaks pick them apart, often leaving part of the bud on the stem in a frayed, fuzzy condition. All birds of this group travel in flocks during the winter and are erratic in distribution. After visiting a locality the may not appear there again fc some years. Buds are not their pr ferred food; seeds and fruits for their usual diet, and as a rule, the birds do little damage to natur forests. Damage to plantation may be severe. Recent studies b Cook and Littlefield on the damag to Scotch pine by grosbeaks indicat that Scotch pine is especially su ceptible to injury.

WILDCATS

The only damage to trees likely to be caused by wildcats is clawing of the bark, and this may seldom be noticed, even where the animals are fairly common. It is included here only because it may prove very puzzling when first seen. It is generally found as long, deep, rather narrow scratches in the bark. The claw marks are cleaner cut, much narrower, and deeper for their width than is bear clawing, which is the only other similar sign found today in the Northeast. They ar made with a downward sweep of th paw and are not to be confused wit the narrow scorings in bark sometimes made by fine points on antler of a rubbing deer, which are usuall made with an upward rather than downward stroke. These cla marks of the wildcat apparently result from the same "claw-sharpening" habits observable in hous cats.

MISCELLANEOUS TYPES OF INJURY

CHEWING TAGS

Thin aluminum, copper, and brass tags are occasionally chewed and rendered illegible by porcupines, and strangely enough, by deer. On tags chewed by porcupines, the animal chiefly responsible for this kind of damage, the marks of the incisors can usually be found, the teeth in some instances having punched through the tag; those chewed by deer, however, are not punctured and have no definit tooth marks on them, but have very wrinkled appearance simila to tinfoil which has been loosel crumpled in a ball and then sprea out again without flattening i down. The deer apparently doe this chewing with its molars, whic have sharp crowns until the anima approaches old age.

GNAWING STAKES

Bears, porcupines, rabbits, squirrels, and woodchucks, all chew to ome extent on plot stakes that have been painted. The reason for this s uncertain, and the chewing itself s very erratic. Some forests have never been troubled in this way, on others extensive replacements have been necessary. Porcupines seem to be the worst offenders, and woodchucks next. Careful scrutiny is sometimes needed to discover the impressions of the teeth on rough stakes.

GNAWING AROUND ENTRANCES TO DENS

In enlarging entrances to dens, especially those in tree trunks, rodents frequently gnaw around the opening. Usually the size of the hole and the tooth marks will suffice for identification of the rodent. Squirrels are the most frequent offenders of this type of wound, which with continual callousing and being repeatedly gnawed may develop confusing abnormality. The injury is negligible, however, as the hole indicates an already badly decayed trunk or branch.

FLOODING OF TREES BY BEAVERS

Trees that have died from being flooded by beaver dams, although indistinguishable from those killed by other types of dams, may sometimes be recognized by characteristics of the site. Chief among these is the uniformity of the contour level above which no otherwise normal tree will be dead, whereas all the trees below have died. In time, as new growth comes in, this situation changes, but the presence on flats of many trees that have been dead about the same length of time is an indication of an old beaver flow which may be recognized many years after the new undergrowth develops.

SUMMARY

A summary of injury by mammals and birds to Northeastern trees and shrubs, showing the parts of plant affected, nature of damage, frequency of occurrence, and the identification characteristics, is presented in table 2, pp. 22–26.

Table 2.—*Summary of injury by wildlife to trees and shrubs in northeastern forests*

Species of wildlife	Parts of plant affected	How damaged	Frequency of occurrence	Identified by—
MAMMALS				
Bear	Branches	Broken down	Common	Broken down at crotches; claw marks.
	Bark	Clawed	Unusual	At "bear trees," by size of claw marks and height above ground.
	Wood	Excavations clawed out.	Common on dead logs.	Very splintery holes, irregular outline; old bee or ant nests.
Beaver	New sprouts and fine twigs.	Clipped off and eaten	Frequent	Location of feeding and slanting cut.
	Bark of trunk and branches.	Gnawed off in place	Unusual	Tooth marks.
	Wood of branch or stem.	Partially or wholly severed.	Usual	Tooth marks; size of cut.
	Entire standing tree	Flooded	Common	Complete kill up to an abruptly changing contour above which no damage is seen.
Deer	Sprouts, twigs, smaller branches.	Broken off for eating	Usual	Rough broken ends; square break; height usually up to 6 feet, occasionally 7 feet.
	Bark on trunks and large limbs.	Stripped off by teeth	May be common	Long narrow strips pulled with few or no tooth marks observable.
		Rubbed off with ant-	Occasional	Antler scoring or shred-

Summary of injury by wildlife to trees and shrubs in northeastern forests—Continued

Species of wildlife	Parts of plant affected	How damaged	Frequency of occurrence	Identified by—
MAMMALS—Continued				
Elk	Sprouts, twigs, smaller branches.	Broken off for eating	Usual	Rough broken ends; square break; height usually up to 6 feet, occasionally 7 feet.
	Bark on trunks and large limbs.	Stripped off by teeth	May be common	Long narrow strips pulled with few or no tooth marks observable.
		Rubbed off with antlers.	Occasional	Antler scoring or shredded bark.
Moose	Sprouts, twigs, smaller branches.	Broken off for eating	Usual	Distinguishable from deer injury only by greater height and coarser branches broken off (up to 1.5 inches in diameter).
	Bark on trunks and larger limbs.	Stripped off by teeth	May be common	Long narrow strips missing, or small patches.
		Rubbed off with antlers.	Occasional	Antler scoring; broken dangling branches.
Mouse: Meadow	Bark on trunk, branches, roots.	Gnawed off	Usual	Size of tooth marks; girdling above roots common.
	Small branches and stems up to ¼ inch in diameter.	Gnawed through	Unusual	Appear like miniature beaver cuttings; tooth marks.
Pine	Bark on trunk, branches, roots.	Gnawed off	Usual	Similar to meadow mouse work, but restricted more to roots.

Table 2.—*Summary of injury by wildlife to trees and shrubs in northeastern forests*—Continued

Species of wildlife	Parts of plant affected	How damaged	Frequency of occurrence	Identified by—
MAMMALS—Continued				
Porcupine	Fine twigs	Clipped and eaten	Common	Location; clean, slanting cut.
	Branches	Gnawed through	Occasional	Up to ¾ inch in diameter; slanting cut; tooth marks.
	Bark on trunk and branches.	Gnawed off in place	Usual	Location and size of gnawed areas; tooth marks.
Rabbit, cottontail; hare, snowshoe.	Fine twigs	Clipped off	Usual	Cottontail rabbit and snowshoe hare injury indistinguishable, but cottontail feeding less likely to be on coniferous growth.
	Bark on stem or branches.	Gnawed off	Usual	
Squirrel, red and gray.	Buds (in place)	Hollowed out	Occasional	On conifers; hole at base; 2 or 3 bud scales removed.
	Twigs and branches up to ⅜ inch in diameter.	Gnawed through; buds or fruits eaten.	Common	Ragged—not like usual rodent cut; location; rasping tooth marks.
	Bark	Gnawed in patches or small strips.	Uncommon	Tooth marks; location.
Wildcat	Bark	Clawed	Unusual	Claw marks.
Wood rat	Bark	Chewed	Rare	Tooth marks.

Table 7.—Summary of injury by wildlife to trees and shrubs in northeastern

Species of wildlife	Parts of plant affected	How damaged	Frequency of occurrence	Identified by—
BIRDS				
Crossbill	Buds	Broken off	Uncommon	Bud taken completely; no marks; usually on conifers.
Finch	Buds	Broken off	Occasional	Bud taken completely; no marks; usually on conifers.
Flicker	Trunk or branch. (Usually decadent.)	Nesting hollow dug out.	Usual	Round external hole 2½ inches in diameter, leading to nest chamber.
Grosbeak	Buds	Broken off	Erratic—usually light, but sometimes heavy, damage.	Bud taken completely, no marks; usually on conifers.
Grouse:				
Ruffed	Buds and small twigs	Broken off	Common	No tooth-like marks; usually high location; twigs usually very ragged.
Spruce	Buds and small twigs	Broken off	Common where bird is found.	No tooth-like marks; usually high location; twigs usually very ragged.
Heron, black-crowned night, and great blue.	Branches and entire tree.	Roosting and nesting produce some mechanical damage, but injury mainly is chemical from the excreta of the birds.	Usual	Trees lose health and vigor, or die; nests, feces, remnants of food scattered about.

Table 2.—*Summary of injury by wildlife to trees and shrubs in northeastern forests*—Continued

Species of wildlife	Parts of plant affected	How damaged	Frequency of occurrence	Identified by—
BIRDS—Continued				
Starling	Branches	Broken off by weight of roosting birds.	Occasional	Broken branches, droppings.
	Entire tree	Chemical injury from excreta of birds.	Occasional	Groups of trees lose health and vigor, or die; droppings.
Sapsucker	Trunk and branches	Holes drilled in bark	Usual	Regular rows of ¼-inch holes around the branch or trunk.
Woodpecker:				
Downy, hairy, and red-headed.	Trunk and branches	Small patches of bark removed.	Usual. Excavations made only occasionally.	Fallen bark scales; small irregular holes in bark.
Pileated, Arctic three-toed, and American three-toed.	Trunk and branches	Holes excavated in wood.	Usual	Chips at foot of tree; in general, large excavations in forest trees are the work of the pileated or the three-toed species.
		Nest holes	Usual	Cylindrical shape.

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FLUCTUATIONS IN THE ABUNDANCE OF THE BLUE CRAB IN CHESAPEAKE BAY

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RESEARCH REPORT 14

FISH AND WILDLIFE SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR

ABSTRACT

An analysis of the catch per unit of fishing effort of blue crabs (*Callinectes sapidus*) in Chesapeake Bay indicates that annual fluctuations in commercial abundance are primarily associated with variable rates of survival of crabs in their first year of life. These fluctuations appear first in the summer catch of 1-year-old immature crabs and are reflected in subsequent fisheries for the adults.

The volume of discharge from the James and Potomac Rivers into lower Chesapeake Bay during the spawning season of the blue crab is negatively correlated with the index of annual abundance of adults taken in the fishery during the second winter following hatching. It is postulated that a heavy river discharge in spring and summer lowers the salinity in the bay to a degree unfavorable to high survival of young crabs, whereas low river discharge serves to increase the salinity and promotes a high survival of young.

No correlation is evident between the relative abundance of adult female crabs and their progeny, based on a study of 13 generations. The size of the spawning stock has not apparently determined the size of the population of crabs surviving to commercial age during this period.

FLUCTUATIONS IN THE ABUNDANCE OF THE BLUE CRAB IN CHESAPEAKE BAY

By JOHN C. PEARSON
Aquatic Biologist, Fish and Wildlife Service

RESEARCH REPORT 14

Fish and Wildlife Service, Albert M. Day, *Director*
United States Department of the Interior, J. A. Krug, *Secretary*

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CONTENTS

Pa
Life history
Production
    Kinds of crabs
    Fishing areas
    Gear
Fluctuations in abundance
    Immature crabs 1
        Soft-crab fishery 1
    Adult crabs 1
        Winter dredge fishery 1
        Summer trotline fishery 1
Causes of fluctuations in abundance 1
    Relation between spawners and progeny 1
    Relation between temperature and abundance 2
    Relation between river discharge and abundance 2
Summary and recommendations 2
Bibliography 2

UCTUATIONS IN THE ABUNDANCE F THE BLUE CRAB IN ESAPEAKE BAY

e blue crab (*Callinectes sapidus* bun) of the Atlantic and Gulf s supports the largest crab y in the United States. This y ranks second in volume and in value among the crustacean resources of the Nation. It iced in 1939 (a representative nearly 77 million pounds of shelled and 6 million pounds of helled blue crabs, the total yielding close to 14 million ds of edible crab meat worth at 3 to 5 million dollars to the men. Chesapeake Bay on the tic coast and the estuarine s of Louisiana on the Gulf now furnish 75 percent of the .

ctuations in the abundance of crabs have occurred over the alf century in Chesapeake Bay year-round crab fisheries have been established. These fluc- ons, reflected in the annual ercial yield, are detrimental to ability of the industry. It is tant in considering the future tation of this renewable re- to determine whether the fishery can be maintained through conservation measures at any particular level of abundance or whether the yield is determined wholly by natural factors.

This report examines the nature and causes of these fluctuations. Several natural factors which appear to regulate the annual survival rate and the abundance of the blue crab are discussed on the basis of available knowledge.

Dr. George A. Rounsefell and Dr. Charles M. Mottley of the Fish and Wildlife Service gave generously of time and advice in the preparation of the statistical phases of this report. Floyd Moore, Samuel Coston, John Byrd, Harwood Sterling, Carl Hoffman, and other members of the crab industry of Chesapeake Bay supplied essential information. The staffs of the Chesapeake Biological Laboratory at Solomons Island, and of the Virginia Fisheries Laboratory at Yorktown, assisted in many ways in the program. These State fishery laboratories have made, and are continuing to make, valuable contributions to our knowledge of the life history of the blue crab in Chesapeake Bay.

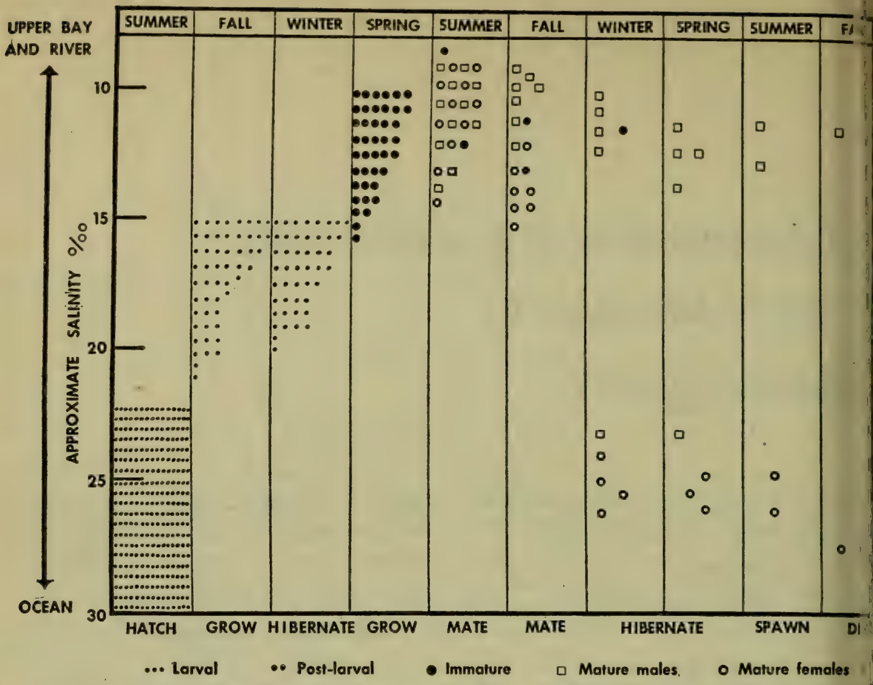

Figure 1.—History of one brood of blue crabs in Chesapeake Bay.

LIFE HISTORY

The life history of the blue crab is best known in Chesapeake Bay because the fishery has been longest established there and the bay provides a suitable environment for the reproduction and high survival of the species.[1]

Each year between May 15 and September 15 a new generation of blue crabs is produced. At this season the female crab extrudes from 1½ to 2 million eggs, and these form a large mass known as the sponge which is firmly attached to the abdomen of the crab. The eggs hatch in about 15 days in the more saline waters of the lower bay. Subsequently, a second sponge of eggs is
produced in the same summer
many females. The young are
like their parents in appearance
after they have shed their la
shells at least five times, du
these stages being helpless memb
of the surface plankton, they assu
a crab-like form and promptly se
to the bottom. These five m
occur during approximately the f
month after hatching. About
times thereafter, before reach
maturity, the crab molts or sh
its shell and expands in size. M
blue crabs attain full growth
mate during their second summ
when from 12 to 14 months of

In Chesapeake Bay young b
crabs, hatched in the lower b
begin a northerly migration i
brackish water, either towards
shallow Tangier and Pocom

---

[1] Major facts in the life history of the blue crab of Chesapeake Bay have been presented by E. P. Churchill in the "Life history of the blue crab," Bulletin, Bureau of Fisheries, vol. 36 (1917–18), pp. 91–128.

nds on the eastern side of the bay
p the various rivers on the west-
shore. Cold weather in the first
ter interrupts this journey, and
young crabs settle to the bottom
emain dormant until conditions
me more favorable. In the
ng their movements are re-
ed, and growth proceeds rapidly
l they reach maturity in summer
arly fall. The female crab is
lized during her last molt and
equently migrates down the bay
vinter in the warmer waters
er the ocean. The adult male
s to remain behind in the deeper
nels of the upper bay and river
aries (fig. 1).

e first spawning usually occurs
e third summer, nearly a year
mating, when the crab is ap-
imately 2 years old. The adult
les move out of the deeper
rs where they have spent the
er and seek shallow inshore
s to spawn, generally close to the
th of the bay. Most female
s reach the end of their life span
the spawning season, moving
o sea or into the deeper waters
e bay to die. Some females are
n to survive, however, into
hird winter, perhaps to spawn
n when 3 years old.

is essential in a study of the
uations in abundance of the
crab in Chesapeake Bay to
ze that the population is com-
l principally of (1) immature
1 year old or less, and (2)
crabs from 1 to 2 years of age.
e exists no evidence to indicate
adults more than 2 years old
ibute appreciably to the brood
in the bay.[2] This observation
asizes that any year-class or
al brood of crabs is produced
almost wholly by a spawning population of 2-year-old adults that have only a single season in which to reproduce a new generation.

A new generation of 1-year-old immature crabs automatically makes up the summer catch of peeler and soft crabs for the soft-crab industry. Early spring catches include, however, many immature crabs of the older year-class, crabs that failed to mature in their second summer and survived the winter to complete growth and attain maturity during the spring. Similarly, a new year-class of adult crabs largely replaces the sexually spent older age group every fall in the hard-crab fisheries to dominate the commercial catch until the succeeding year-class arrives the next fall.

Present evidence suggests that the population of blue crabs in Chesapeake Bay is normally isolated from stocks of blue crabs in other ocean estuaries along the Atlantic coast and that there is little or no intermingling with the crab populations of Delaware Bay and Pamlico Sound. However, it is recognized that schools of spawning crabs frequently move out of the bay in summer and are followed by fishermen for several miles along the ocean shore line.[3]

---

[2] Examination of 15 random samples of the winter population of adult female crabs showed that generally not more than 5 percent of these crabs had previously spawned. However, extensive sampling over several winters is highly desirable.

[3] Studies in progress by Dr. L. Eugene Cronin of the Chesapeake Biological Laboratory have indicated, on the basis of tagging experiments, biometric comparisons, and fluctuations in abundance, that each ocean estuary has its own indigenous population of crabs.

PRODUCTION

KINDS OF CRABS

Both adult and immature blue crabs are taken in the commercial fisheries of Chesapeake Bay. Adult crabs occur in the crab fishery in a numerical ratio of at least 6 to 1 compared to immature crabs and the availability of the latter is sharply limited as to both season and locality. The hard crabs are sold alive by the fishermen, either on a volume or weight basis, at the end of each day of fishing. Adult crabs average between 3 and 4 to the pound, so that from 300 to 400 crabs usually make a standard barrel of 100 pounds. In practice, 10 to 14 pounds of edible meat are picked from 100 pounds of live crabs—the amount varying according to the skill of the picker and the physical development of the crabs. Crab meat is separated and classified for market as claw, flake, and lump or back-fin.

Immature crabs are sought chiefly for the soft-crab industry and are captured either as soft crabs, or, more generally, as peelers (hard crabs preparing to shed within a few days). Peeler and soft crabs are sold alive by count at the end of each day of fishing and provide soft crabs for the market after impoundment and proper handling. A certain mortality of immature crabs occurs from the time the hard or peeler crabs are confined in floats until the soft crabs are ready for market. The degree of this mortality, which may range from 20 to 60 percent of the catch, va widely, depending on natural c ditions such as temperature a salinity of the water, the physi condition of the crabs, and the c they receive in impoundments. S crabs are graded by size (width carapace), as jumbos, hotel prim primes, mediums, and culls.

The combined annual product of soft and hard crabs has sho sharp variations. The catch r from 22 million pounds in 1901 to million pounds in 1915 but dropp to 23 million pounds in 1920. R ord catches of 60 to 69 mill pounds were made annually fr 1929 to 1932. The yield decli again, following a 57-million-pou catch in 1939, to 42 million pou in 1940, and to 30 million pound 1941 (table 1).

FISHING AREAS

Adult blue crabs are available fishermen in most parts of Che peake Bay and its brackish wa tributaries from April to Novem and are taken throughout the y in the lower bay. The life cycle the crab in the bay causes a prep derance of adult males (jim crabs) to occur in the waters of upper bay and most river estua while conversely a concentration adult females (sook crabs) occur the more saline waters near mouth of the bay (table 2). Cr are found in water from seve inches to more than 50 feet in dep During the warmer months of

Table 1.—*Annual catch of blue crabs in Chesapeake Bay, 1880 to 1942* [1]

Year	Crabs, hard		Crabs, soft		Total crabs		
	Maryland	Virginia	Maryland	Virginia	Maryland	Virginia	Both States
	1, 167	2, 139	(2)	(2)	(2)	(2)	(2)
	2, 758	627	1, 636	(2)	4, 394	(2)	(2)
	2, 675	957	2, 209	(2)	4, 884	(2)	(2)
	2, 388	2, 585	4, 056	440	6, 444	3, 025	9, 469
	2, 777	2, 208	4, 829	586	7, 606	2, 794	10, 400
	5, 333	5, 332	4, 116	1, 068	9, 449	6, 400	15, 849
	9, 825	6, 113	4, 303	1, 289	14, 128	7, 402	21, 530
	12, 665	10, 356	5, 733	1, 911	18, 398	12, 267	30, 665
	12, 786	23, 001	7, 587	2, 082	20, 373	25, 083	45, 456
	22, 492	18, 765	7, 602	1, 484	30, 094	20, 249	50, 343
	5, 166	12, 465	3, 897	1, 172	9, 063	13, 637	22, 700
	7, 321	18, 532	2, 325	1, 423	9, 646	19, 955	29, 601
	25, 455	30, 378	2, 645	1, 700	28, 100	32, 078	60, 178
	31, 626	28, 940	5, 313	2, 881	36, 939	31, 821	68, 760
	29, 931	28, 963	3, 911	1, 712	33, 842	30, 675	64, 517
	29, 399	27, 024	3, 540	1, 549	32, 939	28, 573	61, 512
	26, 648	23, 911	3, 449	2, 068	30, 097	25, 979	56, 076
	13, 620	22, 516	2, 288	1, 370	15, 908	23, 886	39, 794
	17, 264	19, 762	2, 556	1, 449	19, 820	21, 211	41, 031
	13, 294	26, 137	2, 268	1, 969	15, 562	28, 106	43, 668
	16, 198	27, 927	2, 154	2, 475	18, 712	30, 402	49, 114
	20, 699	28, 690	2, 898	2, 782	23, 597	31, 472	55, 069
	24, 062	26, 967	3, 233	2, 783	27, 295	29, 750	57, 045
	15, 031	23, 016	1, 790	1, 977	16, 821	24, 993	41, 814
	11, 975	15, 716	836	1, 709	12, 811	17, 425	30, 236
	14, 048	18, 644	1, 645	1, 445	15, 693	20, 089	35, 782

xpressed in thousands of pounds; that is, 000 omitted.

ata lacking.

le 2.—*Sex composition of the catch of blue crabs taken by several types of gear at various localities and periods in Chesapeake Bay*

[Most crabs taken by gear other than scrape and dip net are adult crabs]

ate	Locality	Season	Gear	Number of crabs	Percentage		Source
					Males	Females	
6 17	Lower Bay, Va	Winter	Dredge		20	80	Churchill.
4 25	do	do	do	9, 308	23	77	Sette and Fiedler.
3 44	do	do	do	918	11	89	Pearson.
7	do	Summer	Trotline		16	84	Churchill.
5	Hampton, Va	do	do	2, 743	39	61	Sette and Fiedler.
2	Lynnhaven Roads.	do	do	3, 213	1	99	Pearson.
3	do	do	do	18, 835	4	96	Do.
4	do	do	do	7, 673	5	95	Do.
5	do	do	do	6, 894	2	98	Do.
5	Crisfield, Md	do	do	9, 450	69	31	Sette and Fiedler.
5	do	do	Scrape-dip net	4, 254	48	52	Do.

r they move into shallow areas ter to feed or to spawn and in ter retire to the deeper channels semihibernation. Although ely distributed in the bay, blue bs congregate in certain areas for ding, molting, spawning, and ernating. These regions are well gnized by fishermen who obtain r best catches through knowledge of the environment where crabs gather daily or seasonally in the heaviest concentrations. Variations in the daily catch among individual fishermen are largely attributable to the selectivity of crabs for specific environments at different periods of the day, seasons of the year, and at various stages in their life cycle.

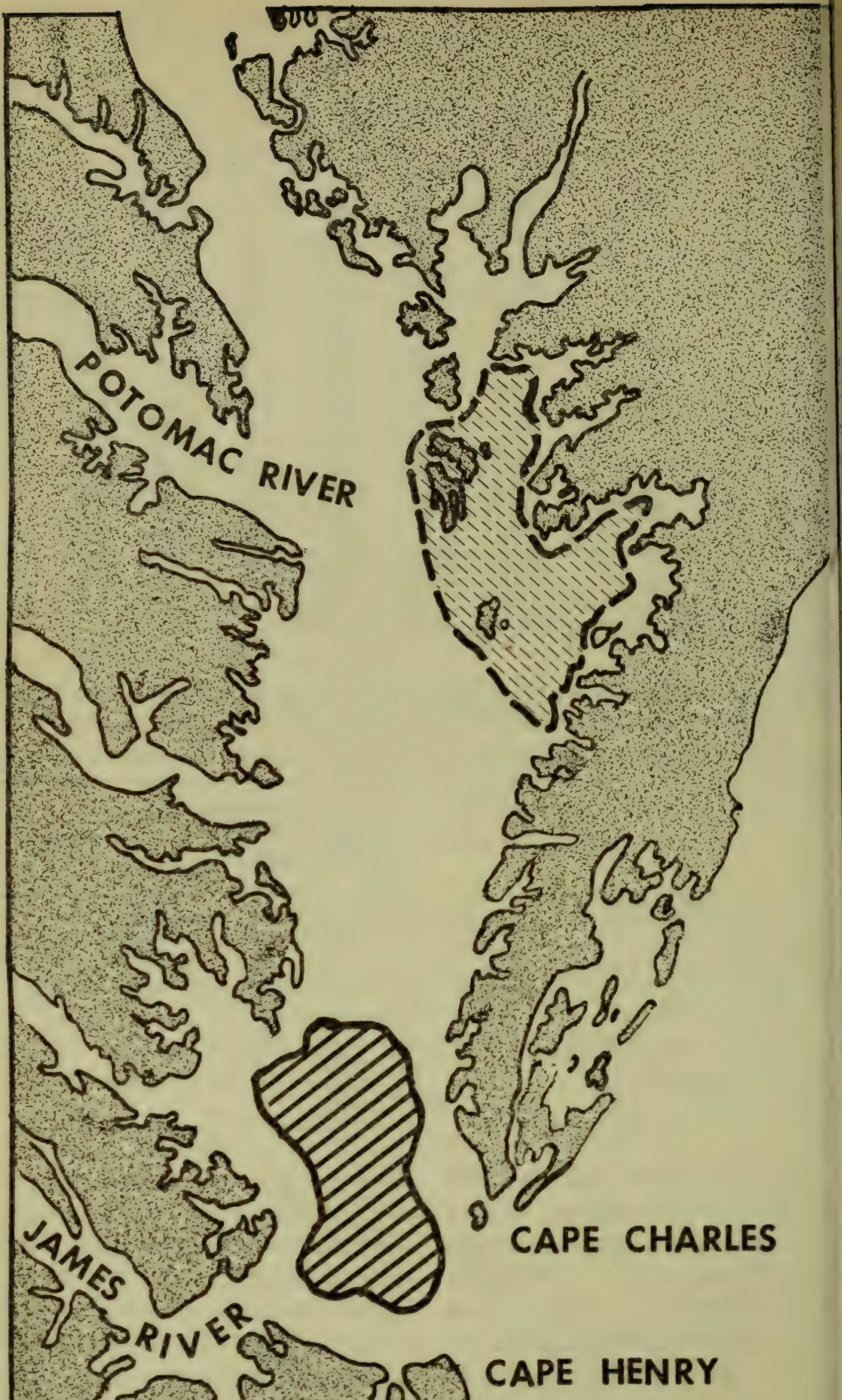

Figure 2.—Map of Chesapeake Bay, showing center of fishery for immature (soft and pe r) crabs within dotted area, and for winter adult crabs within solid line area.

Accordingly, the warmer waters the lower bay shelter winter con- ntrations of adult female crabs, fficient in size to support a dredge hery from December to March; e shallow sand bars and open aches near the mouth of the bay tract schools of spawning crabs, ailable in summer to fishermen erating the efficient patent-rig otline; and the sloping edges of annels in the middle and upper y and in river estuaries afford ncentration points for adult male abs, eagerly sought by trotline d pot fishermen (fig. 2; table 3).

Immature crabs become legally ailable to the soft-crab industry hen they have reached three or ore inches in carapace width. hey are taken commercially from rly May until late September as ey come into shallow waters to olt. The most productive crab- ng grounds in the bay for peeler d soft crabs include the general gion known as Pocomoke and angier Sounds. On the broad, assy flats, especially in the vicini- of Smith and Tangier Islands, ung crabs congregate in large mbers throughout the summer for eir periodic growth stages. How- er, many regions in the middle d upper bay support sufficient antities of immature crabs to pro- de soft-crab fisheries of varying egrees of intensity. Shallow and eltered water with a salinity of out 15 parts per thousand appears be a primary requirement for a ccessful soft-crab fishery. The ottom must be reasonably level for e efficient operation of the scrape d the water quiet and clear for e use of the dip net.

Table 3.—***Number of crabs caught per run of trotline on 3 progressive offshore courses from Lynnhaven Inlet, Va., Aug. 20, 1942, to illustrate the inshore concentration of spawning females.***

[2 runs made along each course. Distances and depths are approximate]

Location offshore	Depth	Number of Adults		Number of immature crabs
		Females	Males	
Yards	*Feet*			
50–450	4–8	176	1	---
50–450	4–8	160	2	---
700–1100	10–14	85	2	9
700–1100	10–14	60	2	3
1900–2300	15–20	3	9	3
1900–2300	15–20	1	2	1

GEAR

Several diverse types of fishing gear are successfully employed in the capture of blue crabs (fig. 3; table 4). Because adult, hard crabs seek food avidly from early spring until late fall, they are readily attracted to trotlines and traps by such baits as salted eel, pickled tripe, and scrap-fish, especially the oily menhaden. The trotline and dip-net combination was formerly the favorite means for taking hard crabs during the warmer months of the year but has been gradually replaced in many sections of the middle and lower bay since 1940 by the wire pot. The latter has the advantage of catching crabs continuously with a minimum of labor but has the disadvantage of requiring a supply of fresh bait at frequent intervals. Fyke nets are widely used in localities where crabs can be intercepted in their movements in and out of creeks and other restricted areas.

The dredge net, a modified form

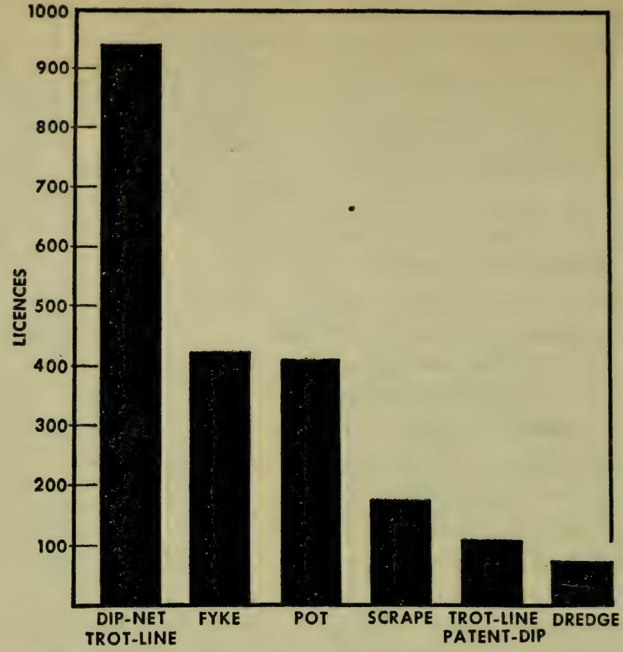

Figure 3.—Types and number of licenses for crab fishing issued by Virginia from April 1 to April 1942. [Data by courtesy of Virginia Commission of Fisheries, Charles M. L ford, Jr., Commissioner.]

of the oyster dredge, is used to capture blue crabs in winter, at a time when they do not seek food and lie semidormant in the deeper waters of the bay. Two dredges are operated simultaneously from a Diesel-powered vessel, manned by a crew of four fishermen. The dre is the only major gear for tak adult crabs that is relatively n selective in action. Crabs m gather in schools and be relativ immobile to make the use of dredge-net profitable.

Table 4.—*Annual catch of blue crabs in Virginia and Maryland by gear the years 1931 and 1941* [1]

Gear	Virginia				Maryland			
	Hard crab		Soft crab		Hard crab		Soft crab	
	1931	1941	1931	1941	1931	1941	1931	194
Trotline	21,354	7,548	----------	370	29,015	11,625	----------	
Pot	----------	5,707	----------	79	----------	350	----------	------
Dredge	7,214	2,117	----------	----------	----------	----------	----------	------
Dip net	44	38	603	456	376	----------	1,725	
Scrape	350	176	1,109	394	538	----------	2,097	
Fyke	----------	129	----------	207	----------	----------	----------	------
Haul seine	----------	----------	----------	----------	----------	----------	87	

[1] The use of the wire pot is the outstanding change in method of fishing during this period. Catch is expre in thousands of pounds; that is, 000 omitted. Estimated conversion factors: 3 hard crabs to a pound, and 4 crabs to a pound.

The immature crab is taken for e soft-crab industry by the scrape, ich is a type of small dredge, and e hand dip net. The scrape, rela-ely nonselective in action, is erated over shallow, level areas open power boats, equipped to ag two scrapes simultaneously. ch boat is manned by a single herman who works from dawn til midday before bringing his tch to the shedding house.

The hand dip net is used as an xiliary to the scrape but is exclu-ely employed by many crabbers certain sections of the bay. It is ost useful in water ill-adapted for agging the sled-like scrape—water either too shallow, too heavily covered with eelgrass, or too restricted to permit maneuvering the power boat and its scrapes. Keen eyes and constant vigilance are essential to the making of good catches with a dip net, but, as a recompense, catches are frequently larger and of better quality than those taken with the mechanical scrape. Both scrape and dip net may be used on the same day by the same fisherman, and separation of the catch on the basis of gear used is not generally possible. The scrape is preferred, however, in most areas with the heaviest concentrations of young crabs.

FLUCTUATIONS IN ABUNDANCE

Fluctuations in the annual abun-nce of blue crabs in Chesapeake y were recorded by Smith (1891) en he noted that some 2,199,931 mature (soft) crabs were taken by 5 fisherman in Maryland in 1887 npared to 3,928,308 immature bs obtained by 773 fishermen in 38. Based on the annual catch man, there occurred an increase 52 percent in the commercial undance of immature crabs in 38 over that of the preceding ar.

The total annual yield of crabs in bay has increased as much as 12 cent and decreased as much as 29 cent from one year to the next. the period from 1929 to 1941 the ch credited to Maryland shows sharpest fluctuations with an rease of as much as 31 percent l a decrease of as much as 47 per-t in successive years (table 1). Although changes in fishing intensity, induced by economic and technical factors, have occurred over the past 15 years, these changes are neither sufficiently pronounced nor so erratic from year to year as to account for these variations in annual catch.

Although total annual yield may provide, under fairly constant fishing intensity, a rough measure of actual abundance, it obviously fails to indicate the nature of fluctuations in the population of crabs. Annual catch on a calendar-year basis includes, for example, part of the population of two successive age-groups of adult crabs, one group of which may be far more abundant than the other. Thus, a high abundance of adults during spring and summer is not necessarily reflected in a comparable level of abundance the following fall and winter. Most adult crabs taken in the former season are a year older than those occurring in late fall of the same year.

Annual production is also responsive to general economic conditions prevailing over a period of years, which serve to alter fishing intensity. The depression years in the early 1930's stimulated fishing intensity by forcing many unemployed people into the crab industry of the bay in efforts to gain a livelihood. Total production was probably larger than might have been the case under better economic conditions. The war years from 1942 to 1945, on the other hand, prompted many men to leave the industry for more lucrative positions, so that the annual yield was more or less stabilized at a low level despite sharp variations in natural abundance of crabs occurring during this period.

The total annual production is a less sensitive measure of natural abundance of crabs than the catch per unit of fishing effort, which is best represented by the yield per man-day or per vessel-day. Every scrape-net operator for immature crabs, or captain of a dredge vessel seeking winter adults, tends to put in a constant amount of time and energy each fishing day, regardless of general economic conditions or the immediate availability of crabs. It is true, however, that when crabs are relatively scarce, some fishermen become discouraged and work fewer days during a season than when crabs are more abundant and the catch provides a greater income. Again, at times when crabs become so plentiful that production must be curtailed because of processing or
marketing limitations, the dre
vessel may be held on a catch li
which usually takes the form
fewer fishing days per season,
though the daily catch also may
limited during periods of exces
abundance or availability.

It is well to remember, as sta
by Van Oosten, Hile, and Jo
(1946), that fluctuations in prod
tion ordinarily exceed those in ab
dance, that is, the increases in
catch tend to be relatively gre
than the increases in abunda
when the latter rises above the av
age, and conversely, the decrea
in the catch tend to be greater t
the decreases in abundance when
the latter falls below the avera
These investigators also noted t
this general relationship betw
abundance and catch has its ori
in the circumstance that fishing
tensity tends to be above aver
when abundance is above aver
and below when abundance is bel

IMMATURE CRABS

SOFT-CRAB FISHERY

The immature blue crab soug
for the soft-crab industry represe
the youngest stage at which cr
are taken in the fisheries, and
usually in its second summer
about 1 year old. This crab affor
through the commercial catch, t
first measurable index of the re
tive abundance of the year-class
crabs hatched the previous ye
Following maturity in late summ
or early fall, these crabs provide t
basis of the hard-crab fishery duri
the ensuing year. A reliable mea
ure of the population of these imm
ture crabs should furnish knowled
of the relative strength of the adu

crab stock, largely of a single year-class, prevailing from one fall to the next.

An index of the annual abundance of year-old immature crabs, based on the catch per man-day, may erve to indicate the relative abundance of each annual brood of crabs. The accuracy of this index is influenced, however, by the fact that fishermen differ widely in ability to catch crabs.

In making an index of abundance of immature crabs, the daily catches of the same fishermen have been compared from year to year so far as data permit. The daily catches of those men who fished for at least two consecutive years have been averaged into 2-week periods, covering the customary fishing season for peeler and soft crabs from May 1 to October 1. This grouping of daily catches tended to minimize extreme fluctuations in catch due to temporary factors, such as bad weather, and enabled proper representation to be given to variations in fishing effort (number of man-days) caused by seasonal availability of crabs and other factors.

As available catch records include those of relatively few fishermen who worked for a long period of years, it was essential to construct a catch relationship based on the ratio of 1 year's catch to that of the previous year, using the daily average catches of the same men. Three series of daily catch records have been used to construct three separate indices of abundance of immature crabs. Series I consists of the catches of 23 fishermen who operated near Deals Island, Md., during a 10-year period from 1935 to 1945 (1940 records are lacking). The catches of at least 8 of these 23 men are represented in the comparative data for every two consecutive years. The data in the three series of catch records are summarized in tables 5 and 6. The method of obtaining the ratio of the catch of 1 year to that of the preceding year is shown in table 7.

Because the availability of crabs and the amount of time spent in fishing varied considerably throughout each season, the average catch for the whole year could not be compared from year to year to calculate the index numbers representing the real abundance of crabs. Accordingly, the average daily catch by 2-week periods in each pair of successive years from 1936 to 1944 was calculated as shown in table 7 (using logarithms for convenience in calculation) to give a series of ratios listed in the seventh column of table 5. In the case of 1944 and 1945 the ratio between the weighted average catches of the 2 years was 1.357; i. e., the abundance in 1945 was 35.7 percent greater than in 1944. This was listed in table 5 as 1.36 by rounding off the figure. Table 7 is given only as an illustration of the method of computing ratios; similar ratios were computed for each of the pairs of successive years for which data are available.

In table 5 these ratios were converted into index numbers, for convenience, using 1935 as the base year with the index of 100. Thus, since the abundance in 1936 bears the ratio of 0.83 to that of 1935, 83 becomes the index of abundance for that year. Similarly, the ratio of abundance of 1937 to 1936 is 0.93.

Table 5.—*Series I and II data used in obtaining an index of annual abundan of immature (peeler and soft) crabs taken by 2 groups of fishermen in Ches peake Bay from 1935 to 1945, and from 1939 to 1945*

[Catch data adjusted for variations in seasonal availability table 7.]

Years compared	Number of crabbers	Fishing days		Catch in numbers		Catch ratio	Index of abunda	
		First year	Second year	First year	Second year		Year	Inde
SERIES I								
1936 to 1935	9	712	654	101, 752	117, 986	. 83	1935	
1937 to 1936	11	883	867	115, 543	123, 124	. 93	1936	
1938 to 1937	13	1, 119	1, 147	149, 792	132, 577	1. 18	1937	
1939 to 1938	10	866	880	164, 714	141, 164	1. 10	1938	
1941 to 1939	8	285	636	16, 958	124, 109	. 18	1939	
1942 to 1941	8	489	364	62, 746	24. 059	3. 39	1941	
1943 to 1942	8	454	484	25, 704	65, 817	. 41	1942	
1944 to 1943	9	568	550	85, 032	37, 121	2. 13	1943	
1945 to 1944	10	666	717	149, 011	112, 240	1. 36	1944	
							1945	
SERIES II								
1940 to 1939	3	191	207	25, 337	59, 020	. 47	1939	
1941 to 1940	3	180	191	27, 831	25, 337	. 83	1940	
1942 to 1941	3	323	278	39, 955	30, 892	1. 92	1941	
1943 to 1942	6	579	595	43, 743	72, 959	. 61	1942	
1944 to 1943	5	417	478	41, 062	36, 945	1. 20	1943	
1945 to 1944	4	403	430	60, 873	43, 555	1. 46	1944	
							1945	

[1] In Series I, 1935 is taken as 100. Series II index is adjusted so the average of all comparable years agrees w index of series I.

Table 6.—*Series III data used in obtaining an index of annual abundance immature crabs taken by same 37 fishermen near Smith and Tangier Islan from 1942 to 1945*

[Not adjusted for variations in seasonal availability.]

Year of catch	Number of crabbers	Fishing days	Catch in numbers	Average per day	Index
1942	37	2, 965	540, 972	182	
1943	37	2, 958	277, 704	94	
1944	37	3, 185	516, 405	162	
1945	37	3, 382	654, 200	193	

[1] Index is based on average of 1942–45 compared with same average in series I.

Thus the previous index, 83, times 0.93 equals 77, the index for 1937.

Similarly, the catch ratios in series II were converted into index numbers, using 1939 as the base year with the index of 100. However, the index of series II was adjusted so that the average of all comparable years agreed with the index of series I. This was accomplished by dividing the sum of the indices of series I by the sum of the indices of series II for comparable years and then multiplying the quotient by the annual index of series I, th obtaining the adjusted index figu for series II.

For series III the annual avera daily catches were converted in index numbers, using 1942 as th base year with the index of 7 Again, this index was adjusted that the average of 1942–45 co pared with the same average series I.

Series II consisted of the dai catches of seven men who work in the region of Crisfield, M

ble 7.—*To illustrate computation of catch per unit of fishing effort of immature crabs in series I for years 1944 and 1945, comparing catches of same 10 fishermen*

2-week period ending	1944			1945			A[1]
	Total catch in number	Number of days fished	Average catch	Total catch in number	Number of days fished	Average catch	
y 14	4, 510	55	82. 0	464	15	31. 0	8. 655
y 28	5, 465	59	92. 6	5, 101	54	94. 4	54. 432
e 11	8, 913	54	165. 0	15, 733	70	224. 6	61. 236
e 25	11, 772	69	170. 5	24, 994	82	304. 5	86. 388
y 9	15, 503	80	193. 9	25, 053	82	305. 3	95. 760
y 23	20, 078	91	220. 3	18, 883	77	245. 0	80. 542
. 6	19, 795	89	222. 0	17, 655	73	241. 9	75. 774
. 20	11, 001	86	128. 0	15, 830	78	203. 0	93. 678
t. 3	9, 211	77	119. 5	14, 836	89	166. 6	88. 165
t. 17	5, 992	57	105. 0	10, 462	46	227. 5	61. 432
Total	112, 240	717		149, 011	666		706. 062
st number of days							623
arithm of ratio × 10							1. 133
io of daily catch, 1945 to 1944							1. 357

---

[1] Logarithm of 10 times average catch in 1944 minus logarithm of average catch in 1945 weighted by least number ays fished in either year.

ring a six year period from 1939 1945. The catches of at least ree of these fishermen are repre- nted in comparative data for every o consecutive years.

Series III comprised the daily tches of the same 37 fisherman o operated in the vicinity of ith and Tangier Islands from 42 to 1945.

There is reasonable agreement tween the indices of abundance comparable years in all series of tch data (table 8). The indices all three series have been averaged give a single index of annual undance of immature crabs. Low undance of crabs occurred in 1941 d 1943 indicating poor survival the 1940 and 1942 year-classes. aks in abundance prevailed in 35 and 1939 indicating high sur- val of the 1934 and 1938 year- sses at least up to 1 year of age. Thus, severe annual fluctuations the abundance of year-old imma- re crabs occur in Chesapeake Bay, as indicated by indices of abundance based on the catch per man-day for three series of data from as many localities in the bay. Variations in annual abundance were especially marked from 1940 to 1945, years when fishing intensity was at a low but consistent level. These changes in abundance are of natural origin and suggest varying annual rates of survival of young crabs prior to the time when they first appear in the fishery.

Table 8.—*Indices of abundance for immature crabs, based on three series of catch data*

Year-class	Index of abundance			
	I	II	III	Combined
1934	100			100
1935	83			83
1936	77			77
1937	91			91
1938	100	83		92
1939		39		39
1940	18	32		25
1941	61	62	61	61
1942	25	38	32	32
1943	53	46	54	51
1944	72	67	65	68

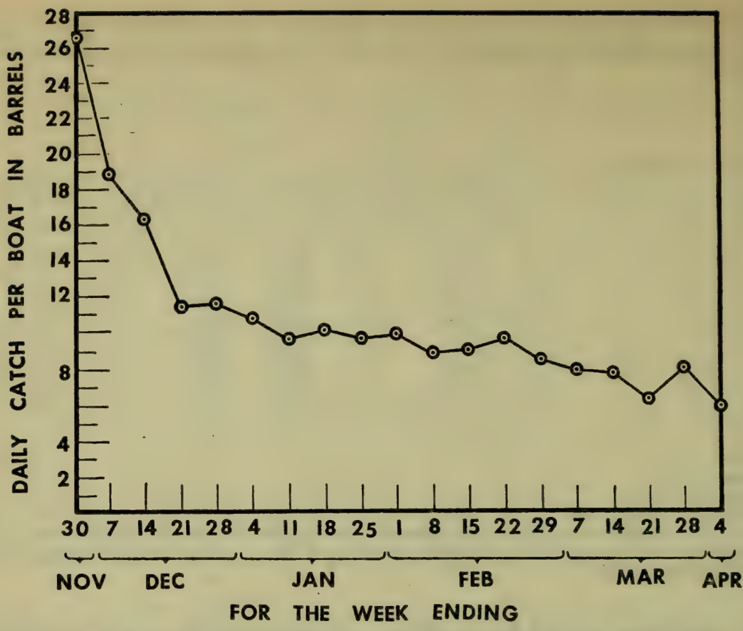

Figure 4.—Norm of seasonal availability of winter adult crabs, based on the daily catch p vessel for two vessels in the dredge fishery in lower Chesapeake Bay, from winters of 1931–32 1944–45.

ADULT CRABS

WINTER DREDGE FISHERY

Adult crabs may be taken in Chesapeake Bay throughout the year, but the seasonal fisheries are largely dependent upon a single year-class or brood of crabs which generally enters the hard-crab fishery for the first time in late summer or early fall. These crabs disappear from the fishery a year later because of natural mortality. As the year-old immature crabs that escape the summer soft-crab fishery attain maturity, the commercial availability of adults of this new year-class increases, reaching a maximum about October in most sections of the bay. Extensive trotline and pot fisheries depend in the fall and during the following spring and summer on this single-year-class of adult crabs.

The methods used by the trotli and pot fisheries make it difficult t obtain extensive series of catch re ords by the same units of fishin gear over a period of years. Th number of pots used by a fisherma may vary widely from week to wee or from season to season, and th length of a trotline and the numbe of baits may change from year t year. A fisherman uses more gea when crabs are scarce than whe they are plentiful.

A consistent unit for measurin the fishing effort for adult crabs i the daily catch per vessel in th winter dredge fishery operating i the lower bay from December 1 t March 31. This fishery depend largely on adult female crabs, a least 90 percent of which belong t a single age-group destined to com prise the spawning stock of the fol

owing summer (table 2). Owing to
he heavy concentration of these
vinter crabs in a restricted area of
he bay, the dredge fishery prob-
bly samples the entire population
f adult females within the bay.

The dredge net is subject to some
ariation in size, the larger vessels
ising a dredge with a 6-foot width
nd the smaller boats dragging a 4-
oot dredge. Theoretically, a vessel
perating the larger dredge should
atch more crabs in a day's fishing
han one using the smaller net.
Iowever, the varying ability and
uck of the vessel captains in locat-
ng the adult crabs, complicated by
he crabs' erratic behavior, cause a
onsiderable range in both daily and
easonal catches among individual
essels, regardless of the size of
redge employed.

A marked decrease in the availa-
ility of crabs occurs each winter as
he season progresses. This con-
ition may be caused both by the
ctual diminishing of the stock of
rabs through fishing and by the
endency of the crabs to scatter dur-
ng the winter following the forma-
ion of compact schools for semi-
ibernation in the early winter.

In computing an index of abun-
ance for winter adult crabs, this
easonal decrease in availability
nust be discounted. This was ac-
omplished by determining an aver-
ge or norm of seasonal availability
om the catches of vessels for which
ecords are available over a long pe-
iod of years. Then, the average
aily catch by weeks of each vessel
articipating in the fishery and for
hich daily catches were available
r all or part of a season or period
f years was compared to this established norm to obtain an index. The norm represented a base index of 100.

Table 9.—*Average seasonal norm of availability of blue crabs in the winter dredge-fishery based on average daily catch of the same 2 vessels from 1931 to 1945*

Week ending about—	Average daily catch	Logarithm of average daily catch
Nov. 30	26.6	1.425
Dec. 7	18.8	1.274
Dec. 14	16.3	1.212
Dec. 21	11.6	1.064
Dec. 28	11.7	1.068
Jan. 4	10.7	1.029
Jan. 11	9.6	.982
Jan. 18	10.1	1.004
Jan. 25	9.6	.982
Feb. 1	9.9	.995
Feb. 8	8.9	.949
Feb. 15	9.0	.954
Feb. 22	9.6	.982
Feb. 29	8.5	.929
Mar. 7	7.8	.892
Mar. 14	7.7	.886
Mar. 21	6.4	.806
Mar. 28	8.3	.919
Apr. 4	6.0	.778

The longest series of records for daily catches of dredge vessels extends from 1931 to 1944 for two vessels operating out of Hampton, Va. The daily average catches for weekly periods have been combined for the 14 years represented in the data to establish a norm of seasonal availability (fig. 4; table 9).

In combining the years, the shape of the seasonal curve was the important feature. Therefore, all 14 years were given equal weight in making the combination. This adjustment was accomplished by increasing or decreasing the weekly averages of daily catches for each year so that the sum of the weekly averages over the period of weeks represented in every one of the years was equal. The range in seasonal availability of winter crabs, based on these 14 years, extends from 26 barrels per vessel-day the first week of the fishing season down to 6 bar-

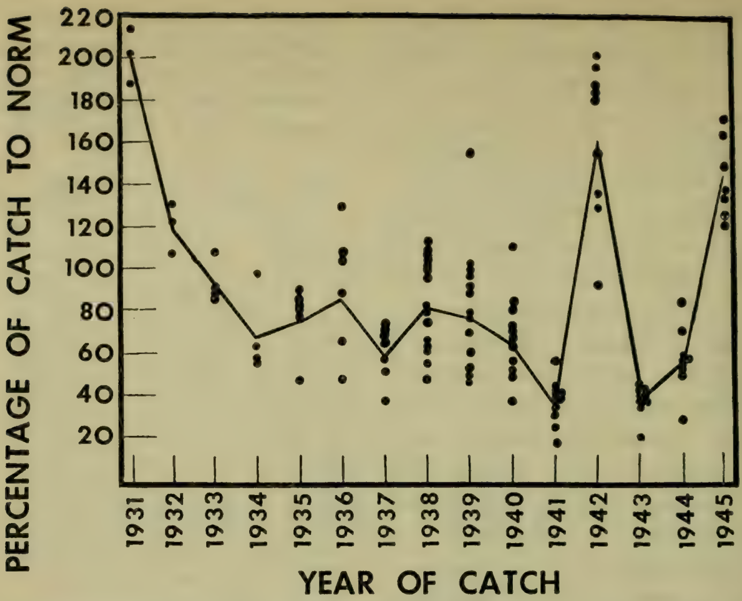

Figure 5.—Range in the index of abundance of winter adult crabs, based on the ratio of t annual catch to the norm for various vessels in the dredge fishery. Line connects the ge metric mean of the ratio of all vessels. One dot represents one vessel's index.

rels per vessel-day, at the end of the season in March.

The daily catches of several dredge vessels are available for obtaining an index of abundance of winter adult crabs from 1931 to 1945. The summarized data used in making the annual indices are given in table 10 while the method for obtaining the ratio of each ve sel's catch to the norm is shown table 11.

The index of abundance of adu crabs for the 15-year period fro 1931 to 1945 is given in table 10 an figure 5. Annual abundance i creased from 0.37 of the norm in t winter of 1941–42 to 1.60 in 1942–

Table 10.—*Index of abundance of winter adult crabs, based on ratio of dai catch to 14-year norm of seasonal availability*

Winter	Number of vessels	Number of fishing days	Catch in barrels	Ratio to norm = index of abundance	Year-cla
1931–32	3	258	5,739	2.01	1
1932–33	3	238	3,494	1.20	1
1933–34	4	275	2,721	.94	1
1934–35	4	250	2,055	.68	1
1935–36	7	355	3,225	.75	1
1936–37	6	307	3,305	.86	1
1937–38	7	429	3,070	.60	1
1938–39	15	727	7,828	.82	1
1939–40	13	833	7,971	.79	1
1940–41	11	737	6,151	.66	1
1941–42	12	757	3,392	.37	1
1942–43	9	465	7,671	1.60	1
1943–44	9	539	2,353	.38	1
1944–45	9	623	4,703	.56	1
1945–46	7	441	7,143	1.43	1

able 11.—*To illustrate computation of catch per unit of fishing effort of adult crabs in winter of 1945–46, comparing average daily catch with the norm of seasonal availability in lower Chesapeake Bay*

Week ending—	Catch in barrels	Days of fishing	Average daily catch	A[1]	B[2]	C[3]
ov. 30	35	1	35.0	2.544	1.119	1.119
ec. 7	119	5	23.8	2.376	1.102	5.510
ec. 14	45	2	22.5	2.352	1.140	2.280
ec. 21	53	3	17.6	2.245	1.181	3.543
ec. 28	33	2	16.5	2.217	1.149	2.298
n. 4	120	6	20.0	2.301	1.272	7.632
n. 11	103	6	17.1	2.233	1.251	7.506
n. 18	68	3	22.6	2.354	1.350	4.050
n. 25	51	3	17.0	2.230	1.248	3.744
b. 1	31	2	15.5	2.190	1.195	2.390
b. 8	79	4	19.7	2.294	1.345	5.380
b. 15	39	3	13.0	2.114	1.160	3.480
b. 22	29	4	7.2	1.857	.875	3.500
b. 29	46	5	9.2	1.964	1.035	5.175
ar. 7	51	5	10.2	2.008	1.116	5.580
ar. 14	25	3	8.3	1.919	1.033	3.099
ar. 21	10	2	5.0	1.699	.893	1.786
ar. 28	7	2	3.5	1.544	.625	1.250
Total		61				69.322
garithms of ratio × 10						1.130
tio of daily catch to the norm						1.37

Logarithm of average daily catch × 10.
Logarithm of average daily catch × 10 minus logarithm of norm.
B weighted by number of days.

d decreased to 0.38 in 1943–44. eavy increases in abundance ocrred in the winters of 1942–43 and 45–46 over preceding years. Sharp declines occurred in the winters of 1932–33, 1941–42, and 1943–44. The year-class of 1930 was the largest while the year-class of 1940 was the smallest represented in these 15 year-classes of crabs.

ble 12.—*To illustrate the relation between abundance of immature and adult blue crabs*

Year-classes in A and B	A	B	C
	Indices of abundance		Abundance of spawners producing crabs in A and B
	Immature crabs [1]	Mature crabs	
		201	
		120	
		94	201
		68	120
	100	75	94
	83	86	68
	77	60	75
	91	82	86
	92	79	60
	39	66	82
	25	37	79
	61	160	66
	32	38	37
	51	56	160
	68	143	38

[1] ndex based on average of indices for series I, II, I tables 8, 10).

Thus, the abundance of a year-class of crabs in Chesapeake Bay is indicated, first in a summer fishery for 1-year-old immature crabs, then in the winter dredge fishery for adult crabs (table 12). The diverse nature of the fisheries for immature and adult blue crabs, and resultant errors in sampling the actual population by means of the catch per unit of fishing effort, have caused considerable variation between the indices of abundance of the two types of crabs in several year-classes, particularly those of 1941 and 1944.

The index of abundance of winter adult crabs is considered a more re-

Table 13.—*Number of adult crabs taken on major spawning grounds in low Chesapeake Bay from June to September, inclusive, 1942–45, together wi number of day-runs of trotline of standard length and average number crabs per day-run of line*

[Catch separated by sex and also 3 spawning stages of female. "No sponge" includes crabs having spawned least once or preparing to spawn. Trotline approximately 1,700 feet long with 650 baits]

Locality	Date	Females carrying—				Males	Number of fishing days or runs of line	Averag numbe of femal per da
		No sponge	Yellow sponge	Black sponge	Total			
East Lynnhaven Inlet	1942	263	194	763	1,220	16	15	
	1943	1,201	1,499	3,768	6,468	209	15	4
	1944	401	634	1,273	2,308	52	16	1
	1945	435	630	1,132	2,197	44	16	1
West Lynnhaven Inlet	1942	144	296	512	952	9	14	
	1943	790	1,677	2,149	4,616	178	15	3
	1944	303	500	775	1,578	55	15	1
	1945	321	618	612	1,551	28	16	
West Little Creek Jetty	1942	68	376	312	756	9	14	
	1943	677	1,095	1,063	2,835	104	15	1
	1944	265	507	395	1,167	44	15	
	1945	267	457	341	1,065	24	15	
Ocean View	1942	108	89	42	239	11	12	
	1943	846	1,725	975	3,546	145	15	2
	1944	288	545	319	1,152	73	15	
	1945	388	857	488	1,733	37	15	1
Total	1942	--------	--------	--------	3,167	--------	55	
	1943	--------	--------	--------	17,465	--------	60	2
	1944	--------	--------	--------	6,205	--------	61	1
	1945	--------	--------	--------	6,546	--------	62	1

liable measure of the actual population of a single year-class than the index for immature crabs because adult female crabs in particular are known to be concentrated in winter in the deeper areas of the lower bay and appear generally well sampled by the dredge fishery, whereas immature crabs, widely scattered in spring and summer throughout the bay, are not available to the fishery in the same high degree as are adult females during the winter months. Again, commercial catches of immature crabs in the first weeks of the fishing season (May) are not entirely made up of crabs from the spawning of the previous year but are composed, in limited measure, of crabs from the spawning of 2 years earlier that failed to attain maturity in their second summer. An index of abundance of commercial-sized immature crabs probably includes a higher proportion of crabs from the older age-group tha the commercial population of winte adults.

SUMMER TROTLINE FISHERY

The catch of the winter dredge fishery, as is indicated in table 2, consist of at least 80 percent adult femal crabs. An index of the annual abundance of these winter crabs shoul normally be reflected in a somewha comparable level of abundance o the brood stock in the following summer. A short series of data, base on the experimental catch per uni of fishing effort of adult females o spawning grounds in the lower ba during spring and summer, provide an approximate verification of th reliability of the winter populatio of adult females as a gage of the siz of the subsequent spawning stock

These data on the abundance o summer adult females consist of th number of crabs taken per run of a nmercial trotline, operated exper- entally over identical courses at ur localities in lower Chesapeake y from June to September 1942–. Usually one run of the trotline s made at each locality every ek from June 1 to September 15. localities were located within the undaries of an area set aside by ginia as a seasonal sanctuary for -bearing crabs and were sub- ted to a minimum degree of com- rcial fishing during the 4-year iod of observation (table 13).

An index of the annual abundance summer spawners from 1942 to 45 has been derived from the aver- daily catch of crabs over the ire spawning season at the four alities. The concentration of wners as well as their spawning velopment was found to increase m Ocean View to Lynnhaven In- , but, regardless of the relative centration of crabs at each col- ting point, fluctuations in the ual spawning stock at the four as appear nearly parallel. For mple, an apparently poor spawn- in 1940 is reflected everywhere in a low abundance of spawners in 1942 while the high rate of survival of the 1941 year-class is indicated by the high abundance of spawners in 1943.

Thus, experimental catch data suggest that annual variations in the abundance of spawning crabs reflect comparable changes in the abundance of adults during the preceding winter. It seems reasonable to assume that an index of abundance of winter adults normally shows the relative strength of the spawning stock, especially as only 6 weeks intervene between the end of the winter dredge fishery (April 1) and the commencement of spawning (May 15).

It is evident that fluctuations in abundance occur among all commercial sizes and ages of blue crabs taken within the bay and must be directly associated with the relative strength of each annual brood of crabs. Changes in fishing intensity, however, and natural factors may affect the degree of these fluctuations as they appear in the seasonal fisheries.

CAUSES OF FLUCTUATIONS IN ABUNDANCE

LATION BETWEEN SPAWNERS AND PROGENY

ndices of abundance are avail- e for the 13 spawning seasons m 1932 to 1944 to use in deter- ning the relationship between the undance of spawners and their geny. The annual abundance of nter adult crabs is assumed to allel the annual abundance of nmer spawners, while the indices abundance of summer immature crabs and of adults of the following winter are assumed to indicate the numerical strength of the progeny from the spawning stock of the previous year (table 12).

Comparison of the abundance of the parent generation of crabs (column C, table 12) with the abundance of their progeny as adults (column B, table 12) yields a coefficient of correlation of 0.134, which is entirely without significance.

This indicates that at the prevailing levels of abundance the abundance of the parent generation is not a significant factor in controlling the abundance of the progeny.

The lack of correlation between abundance of spawners and their progeny applies only to conditions that have obtained during 13 spawning seasons, for which suitable records of the fishery are available for study. The conclusions likewise can apply only to the prevailing levels of abundance of the crab populations and to the present intensity of the fishery. If the rate of fishing and the commercial catch increase materially in the future, it may well be that the spawning population would be reduced to a much smaller number than during recent years, and that the scarcity of spawners would then become the dominant factor in limiting natural reproduction. If such a condition occurs, the protection of spawning stock by the most effective means possible will become necessary.

RELATION BETWEEN TEMPERATURE AND ABUNDANCE

Many fishermen believe that excessively cold weather causes heavy mortality in the population of both immature and adult blue crabs. Roberts (1905), in a report on the crab industry of Maryland, stated: "In 1902 the catch of crabs was small throughout the State. The fishermen attributed this to the severe winter of 1901–02." Exceptionally large numbers of dead crabs have been reported by observers on dredge-vessels in the lower bay during the severe winters of 1917–18 and 1939–40 (the coldest winters on record in the Chesapeake y region).[4]

Possible detrimental effect of he severe winter of 1939–40 is ggested by the extremely sharp ecline in the abundance of 1-year d immature crabs in the summe of 1940 (1939 year-class), followed y a less severe decline in the ab udance of adults of the same gen ation (table 12). However, ther s no apparent correlation betw n winter (January to March) m n air temperatures in the Chesape e Bay area and the series of fluct tions in annual abundance of cr s that has prevailed from 1930 o 1944. Factors other than an oc sional severe winter must be resp sible for most of the variati s in the abundance of blue crabs.

RELATION BETWEEN RIVER D CHARGE AND ABUNDANC

Considerable data exist to in cate a preference of spawning b crabs for water of relatively h salinity in Chesapeake Bay and requirement of high salinity optimum hatching of the eggs a the high survival of larval cra Extensive sampling of the popu tion of spawning blue crabs in area extending from Ocean View Lynnhaven Inlet from May to Se tember 1942 to 1945 revealed much denser concentration of cra bearing eggs in the last incubati stages (black egg-sponge), off Lyn ven Inlet, than at localities lying rther up the bay and in water of sser salinity (table 13). On the sis of observations in Hampton oads and the lower York River in 42, it was further noted that fe- ale crabs bearing eggs in early ages of incubation (yellow egg- onge) usually predominate in the tch. Sponge crabs are taken as up the bay as Tangier Island or yond, as well as up the James ver to Warwick Creek, where the ater in both regions is brackish, t such crabs generally possess a llow sponge. As an interval of veral weeks ensues between the ne the eggs are extruded and be- me attached to the female and the ne they are hatched, spawning abs usually have ample time to igrate a considerable distance wn bay or river to preferred awning areas nearer the sea. edler (1930) recorded tagged adult nales which traveled at least 20 les in 4 days and at least 30 miles a week.

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[4] U. S. Weather Bureau, Climatologi Data Bulletin for January 1940, Maryla and Delaware section, reported: "T January was the coldest since 19 * * * rivers and lakes, the tributar of Chesapeake Bay, and the Upp Chesapeake Bay were frozen ov throughout the month."

These observations on the re- onal distribution of spawning abs, based on the developmental ages of the eggs while in sponge, ow that most spawners move to- ard the ocean and into water of gher salinity prior to hatching of e eggs. Within the short distance 8 miles from Ocean View to Lynn- ven Inlet, the ratio of yellow onge to black sponge-bearing crabs as found to alter appreciably.

Experimental studies by Sandoz d Rogers (1944) have shown the fluence of variable salinity on the tching rate of eggs of the blue crab d on the survival rate of the larvae ld under laboratory conditions. These investigators found that the range in salinity for optimum hatching lay between 23 and 30 parts per thousand. In general, the percentage of hatch increased with a corresponding rise in salinity, at least up to about 27 parts per thousand. It was noted further that the hatching rate usually went below 50 percent when salinity fell below 18 parts per thousand, and that most larvae hatched in the lower salinities were in a prezoeal stage, indicating premature hatching and probable low-survival rate.

Sandoz and Rogers also determined that optimum salinity for molting and growth for the first three larval stages of the blue crab ranged from 21 to 28 parts per thousand. Salinities below 18 parts per thousand and above 29 parts per thousand decreased larval activity. These workers suggest that the summer salinity at the mouth of the bay compares well with the optimum conditions for the development of the eggs and larvae of the blue crab.

As to the range in annual salinity in the bay, Cowles (1930) has said:

> The salinity of Chesapeake Bay, like that of other long bays and estuaries, gradually decreases, with very few exceptions, from the mouth to the head; and the bay is known as a brackish body of water, although the failure, as a rule, of the fresh waters from the land and the saline waters of the sea to mix completely, and the variation in volume of fresh and salt water entering the bay, result in different degrees of brackishness. * * * The evidence on the whole from the 4 years (1916, 1920, 1921, 1922) indicates * * * that in the spring there is a decrease in the salinity of Chesapeake Bay. Such a condition would be expected, if for no other reason than that in the spring months the

Table 14.—*Surface and bottom salinities in parts per thousand at 3 points in lower Chesapeake Bay during the spawning season of the blue crab from May to August 1920*

[Only a single collection made at Thimble Light. Data taken from Wells, Bailey, and Henderson (1929).]

Locality	Surface		Bottom	
	Minimum	Maximum	Minimum	Maximum
Thimble Light	16.3	16.3	25.8	25.8
Cape Henry	19.3	22.7	25.8	31.7
Cape Charles	20.0	28.9	22.6	30.6

maximum discharge occurs in the larger rivers which empty into Chesapeake Bay.

The extent of fluctuations in the salinity of the lower bay during the spawning season of the blue crab is indicated inadequately in a short series of determinations taken from May to August 1920 (table 14). Even during this single period of observations, minimum surface salinities, both at Cape Henry and Thimble Light (approximate east-west boundaries for the major spawning area of the crab in the southern half of the bay) went below the concentrations at which Sandoz and Rogers found the optimum hatching of eggs and normal growth of the crab larvae to occur. Although the female crab keeps the eggs close to the bottom of the bay on the spawning grounds until hatching occurs, it is known from laboratory observations that the larvae are positively phototropic and probably remain for several weeks in the surface layers of water. It is possible for bottom salinity to be favorable for the optimum hatching of the eggs while the surface salinity, fluctuating more widely because of variations in river d charge, may be unfavorable to optimum rate of survival of t young.

It is highly desirable to kn whether salinities during the spri and summer months in lower Che peake Bay fluctuate from year year in sufficient degree to aff the rate of survival of the eggs a the young of the blue crab but, u fortunately, records of salinities lower Chesapeake Bay are not ava able for comparison with those the annual fluctuations in the abu dance of crabs, noted from 1931 1945.

However, accurate records a available on the daily discharge the major rivers flowing into t bay. This discharge can be used a measure of the relative change salinity in the lower bay. For e ample, the James River, abo Cartersville, provides about percent of the annual inflow in the bay (Wells et al., p. 109), ar is the only large stream flowi directly into the lower bay close the spawning areas of the blue cra It is logical to expect that the di charge of this river will have a mo immediate and direct influence the salinity in the region of hea spawning (from Ocean View to Ca Henry) than that of other strean emptying farther within the rece of the bay. Complete records the discharge of the James River Cartersville from 1930 to 1944 a available to compare with the a nual productivity of crabs.[5]

A comparison between th

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[5] U. S. Geological Survey, Water-Supp Papers. South Atlantic Slope, 1930–

able 15.—*Coefficient of correlation (r) between the monthly mean daily discharge of James River at Cartersville and the index of annual abundance of adult crabs for 15-year classes from 1930 to 1944*

Month	r	Month	r	Month	r
nuary	−0.093	May	−0.509	September	−0.024
ebruary	.317	June	.711	October	.283
arch	.082	July	.178	November	.231
pril	.136	August	.672	December	.322

able 16.—*The mean daily discharge in second-feet for May and June of each year from 1930 to 1944 of the James River at Cartersville, compared with the indices of annual abundance of 15-year classes of crabs based on the abundance of adult crabs in the winter dredge fishery*

[The coefficient of correlation is −0.756 based on the logarithm of the index]

Year of river discharge and hatching	Mean daily discharge May and June	Adult crabs		Winter of catch
		Index of abundance	Logarithm of index	
42	10,363	38	1.58	1943–44
40	9,630	37	1.57	1941–42
43	7,503	56	1.75	1944–45
33	6,834	68	1.83	1934–35
38	6,376	79	1.90	1939–40
37	6,307	82	1.91	1938–39
31	6,051	120	2.08	1932–33
32	5,231	94	1.97	1933–34
44	5,188	143	2.15	1945–46
35	4,985	86	1.93	1936–37
36	4,178	60	1.78	1937–38
34	3,841	75	1.87	1935–36
39	3,719	66	1.82	1940–41
41	2,782	160	2.20	1942–43
30	2,355	201	2.30	1931–32

onthly mean daily discharge of he James River and the relative bundance of adult crabs indicates significant degree of correlation etween the amount of stream flow May, June, and August, and the elative success of spawning indiated by indices of abundance of dult crabs (table 15).

It must be assumed that this disharge is directly associated with he salinity over the spawning area uring the late spring and summer onths and that variable salinity ffects the rate of survival of the rood of crabs hatched during this eriod. It follows that a low river ischarge into the bay, resulting in igher salinity, tends to favor a good survival of young crabs and a high level of abundance of winter adults in the year-class affected, whereas a high river discharge into the bay, causing lower salinity, reduces survival of young and the quantity of winter adult crabs.

The discharge of the James River during May and June, a period of heavy spawning of crabs, shows a highly significant negative correlation with the annual abundance of crabs produced in the 15 years from 1930 to 1944. The coefficient of correlation (r) between the river discharge during this 2-month period and the rate of survival (relative abundance) of crabs is −0.756 (table 16, fig. 6). The years of

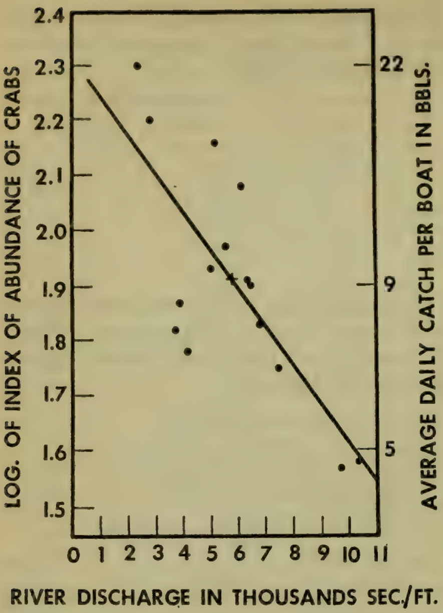

Figure 6. Scatter diagram showing relation between mean daily discharge of the James River at Cartersville in second-feet for May and June of each year from 1930 to 1944, and the rate of survival of crabs each year in Chesapeake Bay as indicated by the indices of annual abundance of 1½ year old winter adult crabs.

maximum discharge in May and June, 1940 and 1942, were accompanied by the lowest annual survival of crabs in the 15-year period. The years with a minimum discharge in May and June, 1930 and 1941, were associated with the highest annual survival of young in this period.

The mean daily discharge of the Potomac River at Point of Rocks during May and June also shows a significant degree of negative correlation with the abundance of crabs (coefficient of correlation is —0.528). However, the heavy discharge of the Susquehanna River fails to show any correlation with the abundance of crabs. It may be assumed that the flow of water into the bay from tl river is separated so far (160 mil from the spawning grounds in t lower bay that it has no appare influence on the survival of you crabs.

It is of interest to note here th minimum commercial yields of cra in Chesapeake Bay in 1920, 192 and 1941 (table 1) were preceded l spawning years when spring a summer discharge of the Jam River was excessive: mean dai discharge for May to August 191 was 10,307 second-feet; for May August 1924, 9,498 second-feet; ar for May to August 1940, 10,8 second-feet. The 37-year mea daily discharge for these montl approximates 5,350 second-feet.

It is possible that if all factors i the complex relation between tl discharge of fresh water into Ches peake Bay and the physical env ronment in the lower bay were full evaluated and more accurate indice of year-class abundance of crab were procurable the natural as we as the commercial abundance c blue crabs might prove to be mor closely correlated with spring an summer river discharge in th Virginia and Maryland drainag basins. A more exact measuremen of the influence of river discharge o the success of spawning of the blu crab can be determined only by th collection of extensive biological an hydrographic data.

On the basis of observations on 1 consecutive year-classes of crabs it is believed feasible to estimat with reasonable accuracy the yiel of crabs per unit of fishing effort t be taken in the fisheries from 1 to years after hatching.

SUMMARY AND RECOMMENDATIONS

. Evidence is given which indi- es that annual fluctuations in the mercial abundance of blue crabs Chesapeake Bay are associated h variable rates of survival of bs in their first year of life. se fluctuations appear first in summer catch of 1-year-old im- ture or peeler crabs and are re- ted in subsequent fisheries for adult crab.

. Variations in abundance of all mercial stages of crabs of the e year-class are generally paral- n trend, although not always in ree.

. No correlation is evident be- en the relative abundance of lt female crabs and their prog- . This conclusion is based on a ly of 13 generations. The size of spawning stock has not deter- ed the size of the population of s surviving to commercial age ng this period. If the rate of ng and the commercial catch ease materially in the future, it well be that the spawning pop- ion would be reduced to a much ller number than during recent s, and that the scarcity of spawn- ould then become the dominant r in limiting natural reproduc-

There is some suggestion that ssively cold weather may reduce availability of immature and t crabs, either by direct mortal- r by making crabs less available e fisheries in those months immediately following a severe winter.

5. The volume of discharge from the James and Potomac Rivers into lower Chesapeake Bay during the spawning season of the blue crab is negatively correlated with the index of annual abundance of adults taken in the fishery during the second winter following hatching. The combined discharge of the James River for May and June has the closest inverse correlation with survival of the annual broods of crabs.

6. It is postulated that a heavy river discharge during the spawning season of the crab lowers the salinity in the bay to a degree unfavorable to a high survival of young crabs, and a low river discharge in the spring and summer serves to increase the salinity and promotes a high survival of young.

7. The indication that river discharge into lower Chesapeake Bay in spring and summer is an important natural factor limiting the population of crabs in the bay and causing severe fluctuations in annual commercial yield justifies further research into the relationship between the physical environment and the survival of crabs.

8. It is recommended that research be undertaken not only to examine more fully the influence of river discharge on the rate of survival of young blue crabs, but to ascertain other factors that regulate the size of the natural population of crabs within the bay.

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SHARK FISHING POTENTIALITIES OF THE PHILIPPINE SEAS

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ABSTRACT

Explorations and investigations to determine the potential value of sharks from the Philippine Seas were carried out by the Philippine Fishery Program in 1948. Exploratory fishing was done with longline and gill net in selected localities from Luzon Island to the Sulu Archipelago. The bulk of the catch by longline consisted of the tiger shark (*Galeocerdo arcticus* Fowler). This species was taken under a wide variety of conditions both as to habitat and fishing effort and seems to be widely distributed in the Philippines. No tiger sharks were taken in the few trials made by gill net.

The liver of *G. arcticus* proved to be low in vitamin A content but the shark has a moderate potential value if used for food provided the hide, oil, and other byproducts can be marketed. Specimens of 3 other species that were analyzed for vitamin A showed some promise but none of the 3 was encountered in sufficient quantity to warrant the establishment of a large-scale fishery. It is recommended, however, that a shark fishery be established on a home or community basis in order to utilize more fully the available marine resources.

SHARK FISHING POTENTIALITIES OF THE PHILIPPINE SEAS

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March 3, 1849

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HARK FISHING POTENTIALITIES F THE PHILIPPINE SEAS

One of the projects that early enaged the attention of the Philipine Fishery Program[1] of the Fish nd Wildlife Service was an experient to ascertain the potential prouction of vitamin A oil from harks and the possibility of estabshing a fishery in the Philippines or the purpose of producing such il. No data are available to indiate that a shark fishery of any apreciable size ever was developed in e Philippine Islands. Most Filiinos have never acquired a taste for e meat from large sharks and the king of sharks for livers or oil eviently has not gained sufficient omentum to initiate fishing for at purpose alone. The chief comercial utilization of sharks before Vorld War II was an export busiess in the fins which amounted to 223 kilograms (18,091 pounds) in 39. This trade, which was reewed in 1946 and produced 9,699 ilograms (21,338 pounds), is curntly in abeyance due to import strictions in China which was rmerly the principal outlet. here is no record of the exportation of shark livers in quantity at any time.

At the time of the inception of the Philippine Fishery Program, it appeared that a shark fishery was one phase of the fishing industry that should be investigated immediately. The value of the sharks to be found in Philippine waters was unknown, as was their abundance. Sharks were, however, generally assumed to be plentiful and therefore represented a resource not being utilized to the fullest extent. Furthermore, due to the report that vitamin A had been synthesized in 1947 and the estimate that in three to five years the synthetic product would be in commercial production and in competition with fish liver oils, it seemed to be to the advantage of the Philippine economy to develop the fish liver industry while there was still a good market.

Interest in the possibility of vitamin A oil production was further stimulated by the numerous inquiries received from both local and foreign sources, particularly from the United States. An official of one American company visited the Philippines to investigate the feasibility of installing a liver oil extraction plant to handle materials from the entire Far East. Others wished to buy livers or oils and still others wished to establish fishing operations. The firm interested in building a plant estimated an annual production of five trillion international units of vitamin A in fish oils would be necessary to warrant such an operation.

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[1] A portion of the Philippine Rehabilitation ogram authorized by the Philippine Rebilitation Act of 1946, Title 50, App. U. S. de, Sec. 1789. The fishery activities are nducted in cooperation with the Philippine ireau of Fisheries.

The experimental fishing vessel *Theodore N. Gill* was, therefore, assigned to explore the waters surrounding the Philippine Islands for sharks as a part of her regular duties. The research vessel, *Spencer F. Baird* was also utilized for this purpose as a part of her functions on one voyage. The experiments were begun in April and terminated in November 1948. The territory covered is shown in figure 1.

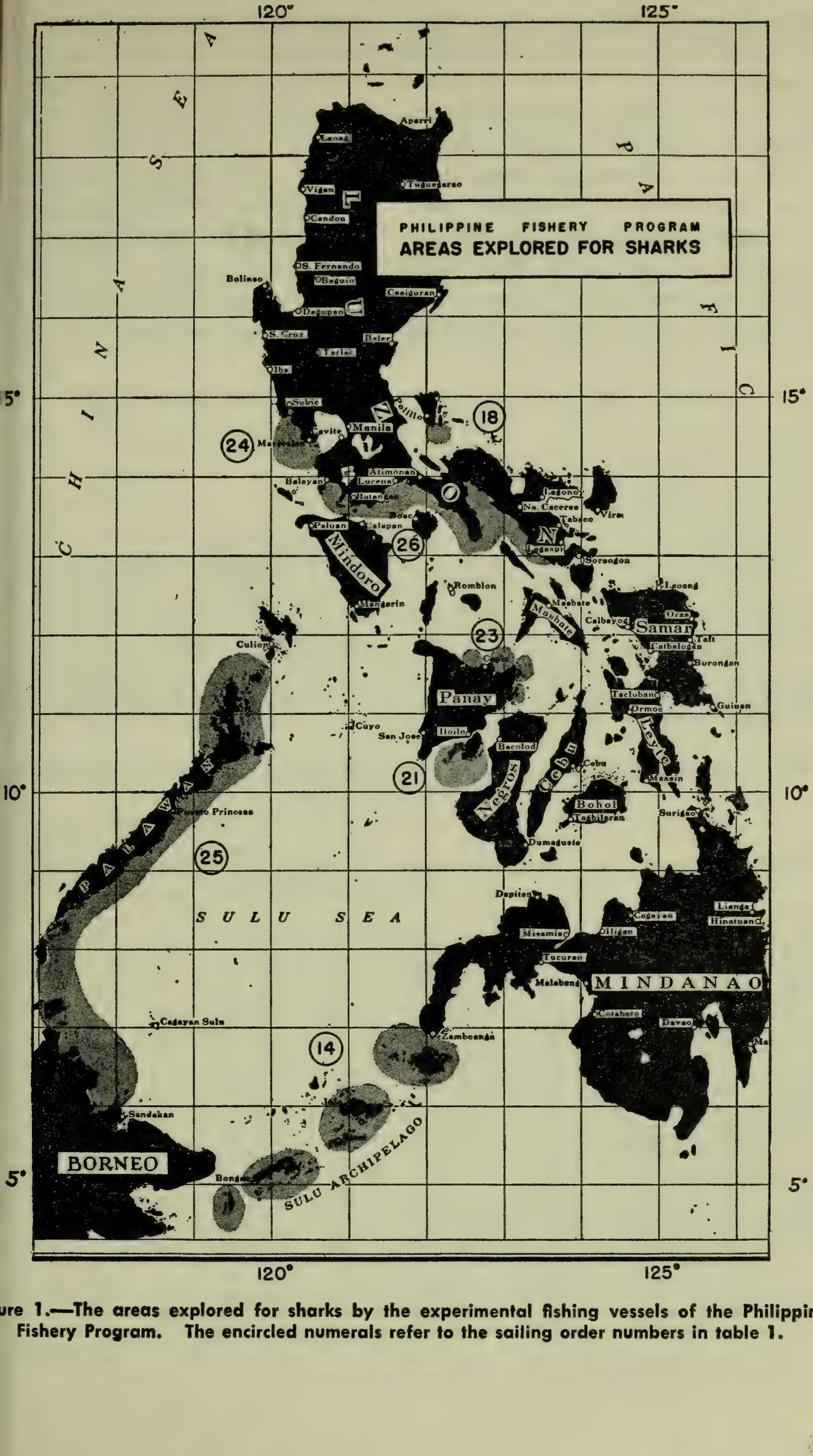
The analysis of oil from shark livers was part of a general program of assaying the vitamin A potential of Philippine fishes, but work on byproducts was designed with the future of shark fishing in mind. Some phases of the laboratory work such as sterol analyses and hide preparation still are in progress.

The data from the field operations were collected and compiled by Donald Kauffman, Augusto Canonizado, and Rollie Sarmiento. The sharks were identified by them with the assistance of A. W. C. Herre, Earl Herald, and Agustin Umali. The *Theodore N. Gill* was under the command of Fred Ziesenhenne for cruises 14, 18, 21, and 23 and Richard Nielsen on cruises 24 and 26. John Lowman was master of the *Spencer F. Baird.* The vitamin A analyses were done by Robert Bereuffy and Cha Rogers with the assistance of gelina C. Aromin and the data w compiled by Rogers. William Hamm assisted in the collection liver samples and hides and c ducted research on hide prepa tion. The Philippine Fish Program of the Fish and Wildl Service is administered by Hu W. Terhune, who planned the ba projects and gave helpful advice the preparation of this repo The field work was under the su ervision of the senior author a analytical work under the juni author. The Philippine Bure of Fisheries, of which Deograci V. Villadolid is Director, coope ated in many ways and suppli part of the fishing gear.

THE REGIONS EXPLORED

Localities for exploration we determined from information su plied by officials of the Philippi Bureau of Fisheries, by interest fishermen, and other citizens wl called upon the personnel of t Philippine Fishery Program, a by observations made by staff mer bers of the Program organizatio Little published information exis on the distribution of sharks in t Philippines other than locali records in reports of general fa nistic researches. In no case, ho ever, were the explorations ha hazard efforts as all trips we planned on the basis of reques from the industry or upon recon mendations from various qualifie sources.

Localities in a general regio were assigned the vessels. Explor



ure 1.—The areas explored for sharks by the experimental fishing vessels of the Philippine Fishery Program. The encircled numerals refer to the sailing order numbers in table 1.

tion of the habitat types, as well as the kind of operation to be followed, were matters left to the discretion of the master of the vessel after consultation with the biologist aboard at the time. Thus experimentation was constantly in progress. Sets were made in the open sea, among islands, and in coves and bays. They were made over different bottom types with anchored and drifted gear, with suspended and pr hooks, and in a variety of depth

The general region of each fi ing effort and the dates that ea area was explored are shown i table 1. In the succeeding tabl 2 to 7, the localities within each ge eral region are listed, together wi the results obtained. In table 9 t average results obtained in each r gion are summarized.

Table 1.—The regions explored for sharks and the dates of the voyages

Sailing order No.	Vessel	Date departed	Date returned	Destination
14	*Theodore N. Gill*	Apr. 2, 1948	May 28, 1948	Zamboanga and Sulu Archipelago.
18	do	June 21, 1948	July 25, 1948	Eastern Luzon.[1]
21	do	Aug. 2, 1948	Aug. 13, 1948	Panay Gulf and vicinity.
23	do	Sept. 7, 1948	Sept. 19, 1948	Panay Island, New Washington, and Jintot Channel.
24	do	Oct. 7, 1948	Oct. 20, 1948	Mariveles, Bataan Peninsula, and Su Bay.
26	do	Nov. 10, 1948	Nov. 24, 1948	Southwestern Luzon.
25	*Spencer F. Baird*	Oct. 30, 1948	do	Palawan, Balabac Strait, S. Sulu Sea.

[1] Only a single effort was made with the shark longline gear on this cruise. This fishing was done in the regi of the Polillo Islands.

Table 2.—Summary of the longline fishing efforts of the *Theodore N. Gill* on sailing order No. 1 Apr. 2 to May 28, 1948

Station No.	Locality	Latitude	Longitude	Number of hooks	Hours fished	Number of hook-hours	Number of sets	Number of sharks per set	Pounds of sharks per set	Poun of liv per s
G-51A	Sibuguey Bay	7°21′ N	122°31′ E	120	20	2, 400	4. 00	0. 75	285	51
G-52	S. Basilan Island	6°33′ N	122°17′ E	140	8	1, 120	1. 87	0	0	0
G-54	W. Basilan Island	6°28′ N	121°39′ E	28	15	420	. 70	0	0	0
G-54A	do	6°28′ N	121°38′ E	28	15	420	. 70	2. 88	157	8
G-54B	do	6°29′ N	121°38′ E	28	25	700	1. 17	. 86	413	76
G-55	do	6°26′ N	121°35′ E	112	21	2, 352	3. 92	1. 82	828	133
G-56	NE. Basilan Island	6°46′ N	122°21′ E	52	15	780	1. 30	0	0	0
G-60	W. Basilan Island	6°51′ N	121°44′ E	134	16	2, 144	3. 57	4. 20	2, 106	396
G-61	N. Jolo Island	6°28′ N	121°8′ E	130	6	780	1. 30	0	0	0
G-62	ESE. Jolo Island	5°49′ N	120°38′ E	140	14	1, 960	3. 27	. 31	56	4
G-63	SE. Pangutaran Group.	5°49′ N	120°19′ E	140	16	2, 340	3. 73	1. 35	292	78
G-64	N. Jolo Island	6°31′ N	121°12′ E	136	15	2, 040	3. 40	1. 20	241	45
G-65	W. Jolo Island	5°58′ N	120°38′ E	84	17	1, 428	2. 38	. 41	139	30
G-66	NW. Tawitawi Island.	5°29′ N	119°54′ E	135	16	2, 160	3. 60	. 56	254	78
G-67	W. Sibutu Island	4°52′ N	119°6′ E	135	17	2, 285	3. 83	1. 04	495	114
G-68	do	4°46′ N	119°12′ E	135	15	2, 025	3. 38	0	0	0
G-69	E. Sibutu Island	4°43′ N	119°34′ E	125	13	1, 625	2. 71	1. 11	75	6
G-71	Tawitawi Bay	5°00′ N	119°54′ E	42	14	588	. 98	0	0	0
G-72	E. Tawitawi Island.	5°00′ N	119°50′ E	84	12	1, 008	1. 68	0	0	0
G-73	do	5°20′ N	120°32′ E	56	16	896	1. 49	. 68	95	1
G-74	do	5°15′ N	120°30′ E	77	13	1, 001	1. 67	. 60	83	1
G-75	W. Tapul Group	5°35′ N	120°38′ E	98	12	1, 176	1. 96	0	0	0
G-76	S. Jolo Island	5°53′ N	121°9′ E	82	18	1, 476	2. 46	. 80	352	62
Average						1, 440. 2	2. 39	. 81	255. 26	47.

le 3.—Summary of the longline fishing efforts of the *Theodore N. Gill* on sailing order No. 21, Aug. 2 to Aug. 13, 1948

tion No.	Locality	Latitude	Longitude	Number of hooks	Hours[1] fished	Number of hook-hours	Number of sets	Number of sharks per set	Pounds of sharks per set	Pounds of liver per set
04C	Negros-Guimaras Islands.	10°44′ N	122°50′ E	90	11.5	1,028	1.71	0	0	0
05C	Panay Gulf	10°06′ N	122°51′ E	28	13.0	361	.6	0	0	0
07	Guimaras Strait	11°05′ N	123°03′ E	49	13.0	683	1.14	2.63	430.0	31.1
11	Concepcion Bay	11°20′ N	123°09′ E	130	16.2	2,102	3.5	.29	120.0	28.57
rage							1.74	.73	135.0	14.92

In this and succeeding tables the hours fished are rounded off to the nearest decimal; computations of the nber of sets were made to the minute the gear was started aboard.

le 4.—Summary of the longline fishing efforts of the *Theodore N. Gill* on sailing order No. 23, Sept. 7 to Sept. 19, 1948

ation No.	Locality	Latitude	Longitude	Number of hooks	Hours fished	Number of hook-hours	Number of sets	Number of sharks per set	Pounds of sharks per set	Pounds of liver per set
20	NE. of S. Gigante Island.	11°36′ N	123°18′ E	42	15.88	666.96	1.11	1.8	270.27	27.02
21	Pilar Bay	11°37′ N	122°50′ E	42	14.22	597.24	.99	1.01	500.0	100.0
121A	do	11°39′ N	122°51′ E	42	14.77	620.34	1.03	4.8	991.26	164.27
122	Sapian Bay	11°30′ N to 11°40′ N	122°37′ E to 122°46′ E	68	19.17	1,303.56	2.17	.46	200.4	41.74
122A	do	11°48′ N	122°36′ E	49	13.5	661.5	1.102	0	0	0
123	Sigat and Apga Pt.	11°49′ N	122°14′ E	62	16.5	1,023.0	1.7	1.76	523.5	104.7
124	do	11°48′ N	122°13′ E	42	16.25	682.5	1.13	.88	247.8	49.56
125	North of Panay I.	11°38′ N	123°09′ E	81	7.38	597.78	.99	2.02	222.22	37.37
126	do	11°38′ N to 11°37′ N	123°09′ E to 123°12′ E	30	12.30	369.0	.615	0	0	0
erage						724.6	1.20	1.414	328.38	58.30

ble 5.—Summary of the longline fishing efforts of the *Theodore N. Gill* on sailing order No. 24, Oct. 7 to Oct. 20, 1948

ation No.	Locality	Latitude	Longitude	Number of hooks	Hours fished	Number of hook-hours	Number of sets	Number of sharks per set	Pounds of sharks per set	Pounds of liver per set
129	Sisiman Bay, Bataan.	14°25′ N	120°31′ E	4	10	40	0.07	14.2	4,957.14	614.28
132	do	14°25′ N	120°31′ E	29	18.38	533.02	.89	0	0	0
133	Mariveles Bay, Bataan.	14°25′ N	120°31′ E	29	18.58	538.82	.90	4.49	934.26	138.2
135	Manila Bay entrance.	14°44′ N	120°13′ E	98	16.75	1,641.50	2.74	1.46	463.36	71.06
136	Port Binanga entrance.	14°44′ N	120°14′ E	57	18.25	1,040.25	1.73	0	0	0
137	Subic Bay entrance.	14°44′ N	120°14′ E	58	18.72	1,085.76	1.8	.55	144.44	26.66
138	do	14°38′ N	120°10′ E	45	20.67	930.15	1.55	0	0	0
139	do	14°40′ N	120°14′ E	45	18.33	824.85	1.37	0	0	0
141	do	14°44′ N	120°13′ E	27	19.08	515.16	.86	.11	417.64	50.58

Table 5.—Summary of the longline fishing efforts of the *Theodore N. Gill* on sailing order No. 2
Oct. 7 to Oct. 20, 1948—Continued

Station No.	Locality	Latitude	Longitude	Number of hooks	Hours fished	Number of hook-hours	Number of sets	Number of sharks per set	Pounds of sharks per set	Poun of liv per se
G-144	Bagac Bay, Bataan	14°37′ N	120°17′ E	65	16.05	1,043.25	1.74	0.57	248.55	38.
G-146	do	14°33′ N	120°20′ E	50	16.92	846.00	1.41	0	0	0
G-147	do	14°32′ N	120°19′ E	50	16.67	833.50	1.39	0	0	0
G-149	do	14°32′ N	120°21′ E	63	16.17	1,018.71	1.70	.59	230.76	30.
G-152	N. Channel, Corregidor.	14°25′ N	120°31′ E	32	16.18	517.76	.86	.11	837.20	188.
G-153	do	14°25′ N	120°21′ E	33	17.25	569.25	.95	2.12	781.91	168.
G-154	do	14°24′ N	120°29′ E	50	19.20	960.00	0	0	0	0
G-155	do	14°24′ N	120°29′ E	52	16.50	858.00	1.43	2.79	972.02	180.
G-156	do	14°22′ N	120°30′ E	100	17.97	1,797.00	3.00	1.67	617.05	103.
Average						866.30	1.44	1.59	589.13	89.

Table 6.—Summary of the longline fishing efforts of the *Spencer F. Baird* on sailing order No. 25
Oct. 30 to Nov. 24, 1948

Station No.	Locality	Latitude	Longitude	Number of hooks	Hours fished	Number of hook-hours	Number of sets	Number of sharks per set	Pounds of sharks per set	Pound of live per se
B-429	S. Dilumacad I., Palawan.	11°11.9′ N	119°20.4′ E	56	22.00	1,232.00	2.05	3.41	946.77	170.4
B-433	E. of Iloc I., Palawan.	11°17.1′ N	119°41.2′ E	56	24.50	1,372.00	2.29	3.06	919.21	173.4
B-435	S. Calasag Bay, Dumaran I.	10°26.1′ N	119°54.5′ E	56	16.00	896.00	1.49	1.34	386.58	73.1
B-438	N. Verde I., Palawan.	10°07′ N	119°15.5′ E	56	19.25	1,078.00	1.80	1.11	251.94	50.0
B-442	Off Puerto Princesa, Palawan.	9°45′ N	118°49′ E	56	18.75	1,050.00	1.75	2.86	456.29	49.0
B-444	Rasa I., Palawan	9°07.5′ N	118°26.8′ E	56	13.00	728.00	1.21	.83	(1)	(1)
B-447	Brooke Pt., Palawan.	8°45.4′ N	117°53.5′ E	56	18.33	1,026.48	1.71	0	0	0
B-450	Ursula I	8°21.5′ N	117°26.8′ E	56	18.50	1,036.00	1.73	0	0	0
B-453	Dalawan Bay, Balabac.	7°54′ N	117°05.3′ E	56	17.75	994.00	1.66	2.41	490.36	83.1
B-456A	Jurata Bay, Cagayan, Sulu I.	6°58′ N	118°29.5′ E	68	14.66	996.88	1.66	0	0	0
B-456B	do	6°58′ N	118°29.5′ E	14	16.25	227.50	.38	0	0	0
B-458	Taganak I., Turtle I. Group.	6°04.3′ N	118°22.7′ E	68	16.00	1,088.00	1.81	.55	212.15	38.9
B-462	Pilas I	6°33.3′ N	121°35.2′ E	68	22.75	1,547.00	2.58	0	0	0
B-466	San Jose, Antique	10°44.1′ N	121°56.1′ E	51	17.00	867.00	1.45	0	0	0
B-468	Pandarochan Bay, Mindoro.	12°12.6′ N	121°09.5′ E	51	14.50	739.50	1.23	0	0	0
B-471	Northern Busuanga.	12°13.5′ N	120°13.7′ E	68	15.00	1,020.00	1.70	2.94	254.71	27.5
Average						993.65	1.66	1.16	244.88	41.6

[1] Only the jaw of a small shark was left; the liver and other parts of the anatomy were eaten away.

THE GEAR

Shark fishing was attempted by two methods, longline trawl and gill netting. The bulk of the effort, however, was confined to longlining.

The longline used was, in the main, patterned after the gear used for the same purpose on the western coast of North America. The mainline was made of ¾-inch diameter manila hemp rope and was assembled as a series of "skates" each of which was 280 feet in length. Each skate mainline had an eye spliced on one end and 7 two-inch rings seized 40 feet apart beginning ble 7.—Summary of the longline fishing efforts of the *Theodore N. Gill* on sailing order No. 26, Nov. 10 to Nov. 24, 1948

tation No.	Locality	Latitude	Longitude	Number of hooks	Hours fished	Number of hook-hours	Number of sets	Number of sharks per set	Pounds of sharks per set	Pounds of liver per set
158	Sisiman Bay, Mariveles.	14°25′ N	120°31′ E	55	12.58	691.90	1.15	0.86	243.47	48.69
161	Pagapas Bay, Batangas.	13°47′ N	120°41′ E	55	15.30	841.50	1.40	1.42	916.42	137.50
162	Balayan Bay, Batangas.	13°53′ N	120°53′ E	48	18.28	877.44	1.46	.68	383.56	89.04
163	do	13°53′ N	120°52′ E	44	17.10	752.40	1.25	0	0	0
165	Batangas Bay, Batangas.	13°46′ N	121°01′ E	80	19.47	1,557.60	2.60	1.93	930.50	173.74
166	do	13°44′ N	121°02′ E	80	16.92	1,353.60	2.26	.88	433.33	79.55
168	Tayabas Bay, Tayabas.	13°53′ N	121°46′ E	50	16.50	825.00	1.38	0	0	0
175	do	13°33′ N	122°17′ E	55	13.67	751.85	1.25	.80	696.00	140.00
178	Ragay Gulf	13°19′ N	122°41′ E	79	15.97	1,261.63	2.10	.44	230.00	50.44
181	do	13°43′ N	122°34′ E	65	17.83	1,158.95	1.93	.96	387.01	76.44
183	do	13°30′ N	123°01′ E	78	19.00	1,482.00	2.67	.38	52.67	9.73
188	Burias Pass	13°12′ N	123°02′ E	75	18.75	1,406.25	2.34	1.20	672.69	139.35
erage						1,080.01	1.82	.80	412.14	78.71

feet from each end. Gangings d buoy lines were snapped in ese rings. A ganging consisted a large swivel-snap spliced to e end of 12 feet of 9-thread eam-tarred manila hemp line to hich was fastened 6 feet of No. 0, ist-link, galvanized iron chain d to which was attached, in turn, No. 20/0 hook. The buoy lines nsisted of 6- or 9-thread, steam-rred manila line with a swivel-ap on one end for attachment to e mainline rings and the other ee for attachment to a steel, foot-ll-type of float, a "Montarro" bber float, or a barrel. The length the buoy line could be varied, us varying the fishing depth.

The vessels usually carried 20 ates of this gear or a total of 5,600 et of line. To each skate was at-ched seven hooks or a total of 0 hooks when all skates were hed. For buoyancy and to mark e gear, a barrel-float was bent on e end of the mainline of each ate and a smaller float was attached to each alternate ring as the gear was payed out.

The fishing efforts made with gill nets used a net 125 fathoms in length and 2.5 fathoms deep. It was constructed of No. 27 cotton seine-twine with an 8-inch stretched mesh. This net was always anchored when fishing.

OPERATIONAL FACTORS

Due to the experimental nature of the exploratory operations in the various regions an evaluation of certain factors, while not in themselves conclusive, seems to be worthy of note as a guide to future work of a similar kind. These factors are largely operational but are also, to a degree, indicative of the natural conditions under which the sharks collected during the survey are to be found.

The results reported are in two forms. Each time the gear was fished is designated as an "effort" irrespective of the number of hooks fished or the time the gear was in the water. The standard unit of effort adopted for purposes of comparison is termed a "set" and comprises 50 hooks fished for 12 hours or 600 hook-hours. The gross weight of the sharks, the number of sharks, and the weight of the liver are cited for each set.

BAIT

A variety of baits was tried but, in general, only material readily available was used consistently. Bait consisted of horse meat, carabao (water buffalo) meat, wild pig, and a variety of fish flesh ranging from sharks to troll-caught species and various bottom-dwelling forms taken by otter trawl. The fishermen preferred red-meat baits because of their lasting qualities on the hook. Many fish-type baits were lost and their loss, whether by stealing or falling from the hooks, renders judgment on the efficacy of a particular bait uncertain.

Altogether, 9 types of baits were tried, as follows: Carabao; horse; shark; fish; carabao and fish; horse and fish; shark and fish; pig and shark; and a horse, carabao, and fish combination. Five fishing efforts were made with carabao alone and 2 of them failed. Only 1 effort was made with horse meat and it resulted in the take of 3 sharks, 2 of which weighed 880 pounds. Shark meat was used 50 times and failed in 18 instances. On 2 occasions fish baits were tried alone, 1 of which produced nothing and 1 took 5 sharks that weighed 433 pounds. Carabao and fish were used in combination twice and both efforts were successful. Horse and fish were tried as bait 14 times and failed b 4. Shark and fish were tried 6 tim and only failed twice. Pig a shark were tried 5 times and all we successful, 7 sharks being taken 2 occasions and 5 on another. T combination of carabao, horse, a fish was used twice; 1 effort pr duced 15 sharks that weighed 7,5 pounds but the other failed.

A consideration of the differen between red meat and fish indicat that the former is better bai When used alone, as it was on onl 6 occasions, red meat produced r sults 4 times; when used 23 times i combination with fish, sharks we taken on 18 such baits. Fish or fis and shark meat in combination, o the other hand, were used 54 time and failed in 24 trials. There a too many other variables that nee to be considered before a definit conclusion can be reached on th subject of bait preference. Even i a preference for red meat seems t be indicated, at the present time i would be difficult and expensive t get such bait in the Philippine Demands for food during Worl War II, both by the Filipinos an the enemy, so depleted the loc meat supply that every effort is be ing made to restore the herds o domestic animals to prewar levels therefore, butchering is rigidly re stricted by law. Horses woul probably prove the most reliabl source of bait for commercial shar fishing.

SELECTIVITY OF GEAR

The hooks used were of the sam size and type throughout the experi ment. They were selective as the took no sharks that weighed less than 16 pounds and the largest individual captured weighed 1,240 pounds, both of which were tiger sharks. The size of the hook would naturally preclude taking small individuals but on several occasions hooks were straightened presumably by larger specimens than those caught. The range in size of the sharks taken was, however, sufficiently great that a fair sample was available for evaluating commercial possibilities.

The gill net, on the other hand took only small specimens. These ranged from a hammerhead shark (*Sphyrna zygaena*) that weighed but 3 pounds to a sawfish (*Pristis cuspidatus*) that weighed 305 pounds. Significantly, no tiger sharks (*Galeocerdo arcticus*) were ever taken in this type of gear.

DEPTH FISHED

The depths of water in which fishing was attempted varied from 5 to 300 fathoms and the average for all efforts was 34.6. The depths of the 28 efforts that failed to produce fish ranged from 5 to 300, the average being 31.5 fathoms while the successful efforts were made in depths that ranged from 7 to 250 fathoms and the average was 36.2. Of the 6 efforts made in water over 100 fathoms in depth, 5 were successful and 1, the deepest, failed; but of the 5 shallow sets, made in water less than 10 fathoms deep, 3 were successful and 2 failed. Thus on the basis of average figures it is doubtful if depths within those ranges was a significant factor in fishing for the sharks reported. The tiger shark was taken over the entire depth range; the single cow shark (*Hexanchus griseus*) in water 180 fathoms deep; and the white-tipped gray shark (*Carcharias albimarginatus*) was taken in approximately 100 fathoms. All other species were taken in shallow water that ranged from 6 to 29 fathoms or at an average depth of approximately 15 fathoms.

TYPE OF SEA BOTTOM

Fishing was attempted over 7 types of sea floor. These were composed of coral, mud, sand, rock, sand and coral, mud and coral, and sand and mud. Three efforts were made over coral, 27 over mud, 24 over sand, 3 over rock, 20 over sand and coral, 2 over mud and coral, and 3 over sand and mud. The efforts were successful over coral 2 times or 66.6 percent, over mud 16 times or 59 percent, over sand 19 times or 80 percent, over rock twice or 66.6 percent, sand and coral 12 times or 60 percent, mud and coral once or 50 percent, and sand and mud twice or 66.6 percent. Of the 47 efforts made over sandy habitats, or sand in combination with mud or coral, 33 or 70 percent produced sharks and 14 or 30 percent failed. Although a preference for sand seems to be indicated, it is probably more significant that sharks were taken over all the types of bottom fished. The largest catch (15 sharks that weighed 7,523 pounds) was taken over a rocky habitat.

DEPTH OF HOOKS

Records were kept of the relative depth of the gear in the water during operations to determine, when possible, if hooks resting on the bottom produced more than hooks suspended. Of the 83 efforts made, 54 were attempted with hooks suspended and 28 with hooks on the sea floor. The suspended hooks produced sharks 35 times and failed to produce 19 times; bottom hooks took sharks 19 times and had none in 9 efforts. On a percentage basis suspended hooks produced 65 percent of the time and bottom hooks, 67 percent. Of further interest is the observation that production from suspended hooks averaged 1.04 sharks and 347.4 pounds per set, while bottom hooks produced 1.14 sharks and 364.9 pounds. Tentatively, it would seem that sharks can be taken by both methods but the largest are taken by bottom sets.

ANCHORED OR DRIFTED GEAR

Data from the 83 efforts were examined to ascertain whether anchoring or drifting the gear was the more advantageous procedure. Drifted gear was tried 16 times and produced results 13 times or 81 percent of the time. Anchored gear was fished 67 times and produced sharks 42 of them or 63 percent. Whether the gear can be anchored or drifted depends on the conditions existing at the time of the operation. This is especially true in exploratory procedure such as here attempted and accounts, to a considerable extent, for the preponderance of anchored over drifted efforts.

PRODUCTION RESULTS

THE SHARKS TAKEN BY LONGLINE

Fourteen species of sharks, representing 6 families and 8 genera, were captured with the 2 vessels. They are listed below according to families.

Family Carchariidae
- *Galeocerdo arcticus* Fowler. Tiger shark.
- *Carcharias limbatus* Müller and Henle. Small black-tipped gray shark.
- *Carcharias menisorrah* Müller and Henle. Gray shark.
- *Carcharias albimarginatus* (Rüppell). White-tipped gray shark.
- *Carcharias melanopterus* (Quoy and Gaimard). Big black-finned shark.
- *Carcharias commersoni* (Blainville). Mackerel shark.
- *Carcharias spallanzani* (Le Sueur). Gray shark.
- *Hypoprion hemiodon* (Müller and Henle). Gray shark.
- *Carcharias* sp.

Family Lamnidae
- *Carcharodon carcharias* Linnaeus. Man-eater shark.

Family Hexanchidae
- *Hexanchus griseus* (Bonnaterre). Cow shark.

Family Scylliorhinidae
- *Scylliorhinus torazame* (Tanaka). Cat shark.

Family Orectolobidae
- One unidentified specimen (nurse shark).

Family Sphyrnidae
- *Sphyrna zygaena* (Linnaeus). Hammerhead shark.

Of the 14 species taken, the tiger shark (*Galeocerdo arcticus*) was by far the most abundant. It constituted 83.8 percent of the total number and 89.3 percent of the weight of all the sharks taken. The catch, summarized in table 8, con-

Table 8.—Summary of the sharks taken by longline showing the relative abundance of each species in the catch

Species	Number	Pounds of sharks	Percentage of total number	Percentage of total weight
Galeocerdo arcticus	125	45,132	83.89	89.32
Carcharias limbatus	4	161	2.68	.32
Carcharias menisorrah	2	325	1.34	.64
Carcharodon carcharias	1	180	.67	.36
Carcharias albimarginatus	2	45	1.34	.09
Carcharias melanopterus	3	1,025	2.01	2.03
Carcharias commersoni	1	235	.67	.47
Carcharias spallanzani	4	440	2.68	.87
Carcharias sp	1	615	.67	1.22
Hypoprion hemiodon	1	205	.67	.41
Sphyrna zygaena	2	430	1.34	.85
Nurse shark (scientific name unknown)	1	225	.67	.45
Scylliorhinus torazame	1	280	.67	.55
Hexanchus griseus	1	1,230	.67	2.43
Total	149	50,528	99.97	100.01

tained but 6 other species that comprised as much as 1 percent by numbers, and only 2 that reached that level by weight.

THE SHARKS TAKEN BY GILL NET

The fishes taken by gill net are summarized in table 10. The 4 sharks captured were species that had also been taken by longline. Two related species, *Pristis cuspidatus*, the sawfish, and *Rhynchobatus djiddensis*, the guitarfish, were only taken by gill net. The catches summarized represent trials by a 125-fathom net fished from a tender on the *Spencer F. Baird*. The dates and locality of the operation are shown in table 11.

PRODUCTION BY SEASON AND REGION

As the vessels were in different regions at different seasons, deduction of comparative potentialities from an exploratory program, such as the one described here, is difficult. Certain differences in productivity per set are apparent in table 9 which may or may not be significant and such differences could only be validated by repeated efforts made in the same locality. The results, from a commercial standpoint, did not seem to justify repeated efforts for that purpose. The greatest production per set was realized off west-central Luzon in October when 1.59 sharks or 589 pounds were taken. The lowest production occurred in Panay Gulf in August when 0.73 sharks were taken per set or only 135 pounds of shark.

On the basis of such evidence as there is at hand, it is doubtful if a seasonal variation of appreciable magnitude would exist in the numbers of sharks in the Philippine seas but variation in the size of the specimens may occur. The simultaneous operations, cruise 26 of the *Theodore N. Gill* and cruise 25 of the *Spencer F. Baird*, took sharks. The quantity taken by the *Baird* in southern and southwestern Philip-

Table 9.—Production per unit of effort by longline (set=600 hook-hours)

Sailing order No.[1]	Dates	Locality	Average sharks per set	Average pounds per set	Average liver weight per set
14	Apr. 2–May 28	Sulu Islands	0.81	255.0	47.
18	June 21–July 27	Eastern Luzon	.69	[2] 477.6	----------
21	Aug. 2–Aug. 13	Panay Gulf	.73	135.0	14.
23	Sept. 7–Sept. 19	N. Panay Island	1.41	328.4	58.
24	Oct. 7–Oct. 20	West-central Luzon	1.59	589.1	89.
25	Oct. 30–Nov. 24	Palawan	1.16	244.9	41.
26	Nov. 10–Nov. 24	Southwestern Luzon	.79	412.1	78.
Average			1.03	348.9	47.

[1] Trips 14 through 24 and trip 26 were made by the *Theodore N. Gill*, and trip 25 by the *Spencer F. Baird*.
[2] Single effort only.

pine waters was greater than the average production for all cruises although the specimens were not so large. Those taken by the *Gill* off southwestern Luzon were not so abundant but were considerably heavier; three weeks earlier the most productive area was encountered farther to the north off west-central Luzon. The data suggest that sharks were present in all the regions during the period of the survey but that there may be differences in the sizes of the individuals in the different regions. The smaller individuals, as determined by the averages, came from the regions west and south of the central Philippines and the larger individuals north of that general region. The largest catch, 15 individuals that had an average weight of slightly over 500 pounds, was taken, however, in the southern area off Basilan Island on cruise 14 at Station G–60 (table 2).

Table 10.—The sharks and related species taken by gill net

Species	Number	Weigh in pound
Carcharias menisorrah	2	18.
Carcharias spallanzani	4	90.
Carcharias limbatus	7	98.
Sphyrna zygaena	1	3.
Pristis cuspidatus	1	305.
Rhynchobatus djiddensis	1	27.
Total	16	542.

VITAMIN A AND OIL CONTENT OF LIVERS

ANALYTICAL RESULTS

Samples of the shark livers taken by Philippine Fishery Program vessels were brought to the shore laboratory for the assay of their vitamin A and oil content. In most cases the samples were frozen aboard the vessels although two experimental lots were salted to determine the effectiveness of that method of preserving the livers. The procedure used in testing for vitamin A potency followed the recommendations of the Joint Government and Industry Technical Committee on Vitamin A.[2] Briefly the method was as follows:

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[2] Proceedings of the meeting of technical representatives of government and industry to discuss standardized methods of vitamin A sampling and assay (June 5, 1944, San Francisco, Calif.) Fish and Wildlife Service, U. S. Department of the Interior. 56 pp. 1944. (Mimeographed.)

Representative portions of large livers were ground in a meat chopper and mixed thoroughly. Portions of the ground livers were then placed in a Waring blender and ground still more finely. Approximately 4 grams of the slurry were pipetted into a tared bottle and weighed; anhydrous sodium sulphate and a measured volume of petroleum ether were added. The sample was then shaken on a machine and centrifuged until the ether layer was clear. A small aliquot of the ether extract was diluted to 25 milliliters with isopropyl alcohol, mixed, and the optical density read on a Beckman Quartz Spectrophotometer at 328 millimicrons. The spectrophotometer had previously been standardized with U. S. P. Vitamin A Reference Standard.

For the oil determination, 20 milliliters of the petroleum ether extract were pipetted into tared 100-milliliter beakers. The solvent was removed by placing the beaker in a steam bath or in a current of air and thereafter by heating in an air oven at 105° C. for 30 minutes. The beaker was then put into a desiccator to cool, after which it was weighed.

The results of the vitamin A and oil analyses made on the shark livers taken during the exploratory fishing are shown in table 12. The weighted averages noted in the table were obtained by the following calculation and are reported in that way as they are equivalent to results that would be obtained by taking composite samples for each species,

Weighted averages (calculated separately for each species):

Percentage oil:

$$\frac{\text{Total oil weight}\times 100}{\text{Total liver weight}}=\text{Weighted average percent oil}$$

Vitamin A per gram of oil:

$$\frac{\text{Total units vitamin A}}{\text{Total grams of oil}}=\text{Weighted average of spectrophotometric units of vitamin A per gram of oil}$$

Vitamin A per pound of liver:

$$\frac{\text{Total units vitamin A}}{\text{Total pounds of liver}}=\text{Weighted average of spectrophotometric units of vitamin A per pound of liver}$$

Table 11.—Summary of gill-net fishing efforts of the *Spencer F. Baird* on sailing order No. 25, Oct. 30 to Nov. 24, 1948

Station No.	Locality	Latitude	Longitude	Number of sharks	Pounds of sharks	Pounds of liver
B-424	Endeavor Strait, Palawan	10°59′ N	119°17′ E	3	16	0.5
B-425	Alligator Bay, Malampaya Sound	10°51.3′ N	119°17′ E	3	345	19.4
B-427	Bolalo Bay, Palawan	10°56′ N	119°14′ E	0	0	0
B-429	Dilumacad Island, Palawan	11°11′ N	119°20′ E	0	0	0
B-433	Iloc Island, Palawan	11°17′ N	119°41′ E	2	50	4.6
B-439	Reinard Island	10°09′ N	119°14′ E	6	92	3.2
B-441	Puerto Princesa	9°45′ N	118°43′ E	1	5	.1
B-448	Ipolote Bay	8°46′ N	117°49′ E	1	7	.2
B-451	Ursula Island	8°19′ N	117°30′ E	0	0	0
B-454	Calandorang Bay, Balabac	7°59′ N	117°03′ E	0	0	0
B-456	Jurata Bay, Cagayan Sulu Island	6°58′ N	118°29′ E	1	27	.1
B-461	Pilas Island	6°36′ N	121°36′ E	0	0	0
Average				1.4	43.5	2.3

and present a truer picture of the value of the livers from a commercial standpoint.

Of the 16 species of sharks and related forms tested, 3 appeared to have commercial possibilities, namely, the gray shark, *Carcharias spallanzani;* the mackerel shark, *Carcharias commersoni;* and the hammerhead shark, *Sphyrna zygaena.* The big black-finned shark, *Carcharias melanopterus*, had a high enough total vitamin content to qualify but it is doubtful if the sample should be classified as representative.

Where a limited number of liver samples of species is available for testing, the values must be considered with some skepticism because occasionally a freak will be found which is not representative of the species. An example is the sample from the male of the species *Carcharias melanopterus*, the big black-finned shark, which had

Table 12.—Vitamin A and oil content of sharks and related species [1]

Species name				Arithmetical average			Weighted average		
Scientific	English	Vernacular	Number and sex of samples	Length of fish	Weight of fish	Weight of liver	Oil content of liver	Vitamin A content of oil (thousands of units)	Vitamin A content of liver (millions of units)
				Cm.	*Lbs.*	*Lbs.*	*Per cent*	*Spectrophotometer units per gm.*	*Spectrophotometer unit per lb.*
Carcharias albimarginatus.	White-tipped gray shark.	Kaitan puti	1 M	114	20.0	0.8	51.8	5.19	1.22
Carcharias commersoni.	Mackerel shark.	Bagsak	1 F	245	235	12	38.8	80.6	14.2
Carcharias limbatus	Small black-tipped gray shark.	Kaitan	5 M 5 F	112.7	21.4	.76	27.8	22.7	2.86
Carcharias melanopterus.	Big black-finned shark.	Lumba	1 F	262	345	43.9	71.1	4.81	1.55
			1 M	145	60	[2]	12.9	302.0	17.7
Carcharias menisorrah.	Gray shark	Bagsak	5 M 3 F	139.4	21.5	4.95	59.6	14.7	3.98
Carcharias spallanzani.	Gray shark	Bagsak	2 M 2 F 1 (?)	153	92.4	13.2	66.4	27.7	8.59
Carcharias sp	Gray shark	Bagsak	1 M	113	43.6	1.5	9.7	715.5	31.4
Carcharodon carcharias.	Man-eater shark.	Pating	1 M	200	180	14.0	69.6	2.09	0.66
Galeocerdo arcticus	Tiger shark	Kaitan mangali.	18 M 20 F	301	417	91.5	79.5	2.39	0.864
Hexanchus griseus	Cow shark	Pating	1 F	385	1,230	190	77.2	4.32	1.52
Hypoprion hemiodon.	Gray shark	Pating	2 M	55.0	3.6	.14	58.5	5.17	1.37
Nurse shark (scientific name unknown).	Nurse shark	Pating	1 (?)	275.0	225.0	28.0	71.8	2.64	.86
Pristis cuspidatus	Saw-fish	Tagan	1 M 1 F	419	393	26.7	60.6	3.99	1.10
Rhynchobatus djiddensis.	Guitarfish	Pating sod-sod.	1 M	136.0	27.0	.09	5.8	32.8	.87
Scylliorhinus torazame.	Cat shark	Pating	1 F	260	280	56.0	89.8	10.4	4.30
Sphyrna zygaena	Hammerhead	Binkungan	3 M 1 F	172.6	109.1	8.05	59.1	35.9	9.64

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[1] In addition to the data from sharks and related species taken during the course of the explorations recorded here, data from sharks of the same species taken by other operations of the Philippine Fishery Program were made available and are included in this table.

[2] No data.

320,000 spectrophotometer units of vitamin A per gram but only 12.9 percent oil. In this case the total vitamin content is high enough to make the liver reasonably valuable but the low oil content would indicate that the shark might be in poor physical condition and not typical.

The only species taken in sufficient quantity to provide a representative sample was the tiger shark (*Galeocerdo arcticus*) from which 38 liver samples were tested. Unfortunately, this shark, which appears to be the most abundant variety in Philippine waters, has a liver of low vitamin A potency, the weighted average of all samples being only 2,390 spectrophotometer units per gram of oil.

COMMERCIAL POSSIBILITIES

When reference is made to the commercial possibilities of the shark liver oils, the value of the liver for export is the main consideration, since there is no market for vitamin A-containing livers in the Philippines at the present time. Shark livers with 40 percent oil or more, and having 5 million spectrophotometer units of vitamin A per pound were selling for a few cents over a dollar a pound at the fish liver auction in San Francisco as of the end of January 1949. Livers from the few sharks discussed in the above paragraph would all be in that approximate range although the market price is likely to fluctuate considerably at times.

It has been learned from a fish buyer in the United States that the clearance of a shipment of livers weighing about 2,000 pounds would cost approximately $13; the cost of sampling and analyzing, $35; the cost of freezing, $10; and the cost of repacking, $37. The buyer charges a 5-percent commission to handle livers shipped to him on a consignment basis; so if the livers sold for $0.50 a pound (a conservative figure for the livers from the fish mentioned above) the seller would pay $50 commission on a ton. If the livers were shipped in frozen storage the charges would be $61 a space ton, or the salted product could be sent for about one-half that amount if not held in refrigerated or freezing storage. The seller would, therefore, receive in the neighborhood of $800 for a shipment of a ton of livers.

At least two shark liver buyers have operated in the Philippines since the end of the war. One has returned to the United States but the other, until recently, was sending an occasional shipment of livers to a firm in California. The extent of this business can be judged only from the export data obtained from the Philippine Bureau of Fisheries for 1947 and 1948, the only years for which records are available:

Year	*Kilograms*	*Pounds*	*Pesos*	*Dollars*
1947	2,103	4,626	1,200.40	600.20
1948	615	1,353	358.00	179.00

On the basis of these figures the average price received was $0.13 a pound which appears to be low in view of the shipping costs and other incidental expenses.

From data collected during the exploratory fishing with the Philippine Fishery Program vessels it is evident that an average of 1 shark can be caught per set of 50 hooks fished for a period of 12 hours and that 84 percent of the total catch are tiger sharks. Livers from tiger sharks, however, are of such a low vitamin A potency that it would not be profitable to export them. The four species that had livers of export value were not caught in sufficient quantity to warrant an intensive fishing effort by mechanically powered vessels.

The possibility that concentrations of more valuable species may occur in some parts of Philippine waters is not precluded, as for example, at certain seasons of the year when following schools of food fishes. It is also possible that the use of other types of gear or bait, or that fishing at other depths might result in catches of more sharks with livers of higher average potency. However, in the one or two instances in which reports of large numbers of sharks were followed up by actual fishing trials, it was found that only the normally expected catch of sharks could be taken.

Referring again to the catch record and assuming that 2 sets comprising 100 hooks could be fished each day there would be a daily take of 2 sharks or 90 pounds of liver. At the most a vessel would be able to fish 300 days a year; thus the annual weight of liver per vessel would amount to 27,000 pounds, which at an average of 864,000 spectophotometer units a pound (for tiger sharks) would give an annual yield of 23 billion units. Recalling that the representative of an interested vitamin oil company had estimated a sustained annual take of livers containing 5 trillion units of vitamin A necessary to justify the establishment of an oil extraction plant in the Philippines, it is found that a fleet of 217 vessels, which would probably have to bring in the catch from widely scattered points in the Islands, would be required to supply such a plant. The powered fishing fleet currently operating in all fisheries in the Islands is approximately of that size.

Another factor to be considered is the capacity of the shark fishery to stand up under continued fishing. An intensive fishing effort probably would soon deplete the stock of the local population that stays close to a given area. Fishing for migratory sharks following pelagic fish, the other source of supply, would undoubtedly be less profitable than catching the pelagic fish.

SHARK BYPRODUCT POSSIBILITIES

OIL

Shark-liver oil can be used for other purposes than as a source of vitamin A but its value for such uses is much less. It may be used, for example, as a fuel, for the treatment of leather, in the tempering of metals, for oiling bancas and in other ways. In addition to vitamin A, another component of shark-liver oil is cholesterol which may have value as a base for the synthesis of vitamin D or in the manufacture of hormones. The isolation of the sterols from tiger shark livers is one of the projects planned for fu-

re study in the Philippine Fish-
ry Program.

IDES

The subject of utilization of the
ides always arises in considering
shark fishery. Sharks taken dur-
ng the exploratory fishing done in
is program were skinned and the
ides saved if large enough and
ree from fighting scars or other
erious blemishes. After fleshing,
he hides were held in freezing stor-
ge aboard the vessels until they
ere brought to the shore labora-
ory where they were salted. Stud-
s made on the removal of sha-
reen indicated that an overnight
aking in a 20 percent hydrochloric
cid solution loosened the particles
ufficiently so that they could be
emoved readily by scraping. Sam-
les of deshagreenized hides were
ken to a tannery on the outskirts
f Manila to determine if local tan-
ing methods could be used. The
nner reported that the chemicals
nd treatment ordinarily applied
carabao and goat hides did not
sult in a satisfactory leather. It
planned to conduct further exper-
ents in tanning procedures.

Prices quoted as of March 1949
nged from $0.70 for a 35-inch
de to $5.40 for one 126 inches long
ith an additional 20-percent
nus for hides having no holes or
tten spots.

NS

Dried shark fins are in consider-
le demand by the Chinese for use
making shark-fin soup. Fins
ken from the sharks during the
hing operations were dried in the
sun after dipping the cut ends in salt. The dried product was submitted to a Chinese buyer and his valuation on the fins, which were from tiger sharks, was 1 to 1.20 pesos a kilogram ($0.23 to $0.27 a pound). The fins with the skin removed and the cartilaginous pieces separated sell for 9 to 12 pesos a kilogram ($2.05 to $2.73 a pound). Salable dried fins from the average tiger shark will weigh about 3 pounds.

MEAT

The flesh from large sharks is not highly regarded among the Christian Filipinos. However, in the Mohammedan or Moro country, particularly around Jolo, good-sized sharks may be seen in the fish markets. They are usually steaked and sometimes a piece of the liver is sold with the flesh.

Some experimental work has been done with shark meat for food. The meat has been salted with brine and as a dry pack, smoked, and cooked in various ways. Dry-salted shark meat was found to be satisfactory for making stews and chowder, but the brine-salted product was not so palatable. Smoking also failed to yield a desirable food item. The use of an acid medium such as tomato sauce, or presoaking in a solution acidified with lemon juice or vinegar not only resulted in a more tender product but also eliminated the “sharky” odor during cooking. It is well recognized that shark flesh contains urea which breaks down under certain conditions, giving off ammonia, to which is attributed the undesirable odor of sharks. The acid treatment appeared to neutralize this action.

MEAL

Another possible use for the flesh of sharks is in the manufacture of fish meal. A small-scale press and grinder as described in Fishery Leaflet 135[3] was built and found to function satisfactorily in the preparation of meal for drying. The finished meal could be used as a protein supplement for animal feeding and also as a fertilizer, which is approximately 40 to 60 percent of its value when used as meal.

TEETH

Shark teeth represent another small but salable item that can be obtained from sharks. A price of $0.50 per 100 was the quotation in 1945 and a shark having several rows of teeth would be worth $1.50 to $2 for the teeth alone.

SUMMARY

A study of the component parts of two tiger sharks weighing 440 and 360 pounds revealed the following percentage break-down:

Item	*Percent*
Fins	4
Liver	22
Viscera	8
Head	19
Meat (including backbone and fleshings from the hide)	[1] 37
Hide (fleshed)	10

[1] 27 percent without the fleshings.

The percentage of liver is higher in these two specimens than the over-all average for all sharks taken during the operation, bu checks well with that for all tiger shark livers weighed.

In summary, the following figures are obtained on the total valu of sharks that might be taken i fishing off the Philippine Islands using the average tiger shark from table 8 as an example (weight, 41 pounds; length, 301 centimeters liver weight, 91.5 pounds):

Fins (3 pounds at 23 cents a pound)	$0.6
Liver oil (using a steam-jacketed kettle and no centrifuge, it was found possible to get a yield of 65 percent oil from tiger-shark livers. From 91.5 pounds of livers, 59 pounds or 8.5 gallons could be obtained. Assuming it to be at least as valuable as crude menhaden oil it should bring $0.15–$0.16 a pound or approximately)	9.0
Hide (an intermediate value)	3.0
Teeth	1.5
Shark meat as meal (from a 417-pound shark approximately 154 pounds of flesh could be converted to fish meal. This would amount to 20 pounds of dried meal figuring a yield of ⅙ to ⅛ the weight of scrap as meal. At $60 a ton, the 1945 price for shark meal having 50 percent protein, it would amount to)	.6
Shark meat as human food (not enough large sharks are marketed to be able to learn what the price for the meat would be, but on the basis of the price asked for other fish, $0.10 a pound would not be unreasonable. The 112 pounds of meat without the fleshing would therefore be worth approximately)	11.2
Total value using the meat for meal	14.8
Total value using the meat for food	25.4

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[3] Guide to commercial shark fishing in the Caribbean Area. Anglo-American Caribbean Commission. Fishery Leaflet 135, Fish and Wildlife Service, U. S. Department of the Interior. 149 pp. 1945. (Processed.)

The values given above are gross ince the expense of shipping hides nd oil would have to be deducted. t would appear that $15 to $20 per hark could be realized, or $30 to 40 for two sharks where 100 hooks vere set for 12 hours. A minimum f 4 men would be needed on a owered vessel and at the current ay rate of $3 to $5 a day for fishrmen there would not be much rofit left after the vessel's operatng expenses were paid.

RECOMMENDATIONS

Although a large-scale shark ishery for vitamin A oil and by-roducts cannot be recommended it is believed that proper utilization of the sharks by fishermen is possible throughout the islands. Such utilization would produce cash income from a resource that is not being fully utilized at this time. It is recommended that sharks be fished for by longlines since a fishery of this type could be conducted without interfering appreciably with other routine and the gear is less expensive. It is finally recommended that a shark fishery be established as a home or small community cooperative industry to utilize all available labor to the greatest degree.

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NOTES ON THE BIOLOGY OF THE TIGER SHARK (*Galeocerdo arcticus*) FROM PHILIPPINE WATERS

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RESEARCH REPORT 16

FISH AND WILDLIFE SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR

ABSTRACT

Data on 43 tiger sharks *(Galeocerdo arcticus)* taken on long-line trawls in Philippine waters by the motor ship *Theodore N. Gill*, exploratory vessel of the Philippine Fishery Program of the U. S. Fish and Wildlife Service, are presented. Adult sharks and unborn pups are described, the weight-length and body-weight to liver-weight relationships are summarized, and fecundity and size at sexual maturity are discussed. Food habits are of interest as the sharks under consideration were dependent upon natural food rather than the offal noted in previous observations.

NOTES ON THE BIOLOGY OF THE TIGER SHARK (*Galeocerdo arcticus*) FROM PHILIPPINE WATERS

By DONALD E. KAUFFMAN

Aquatic Biologist

March 3, 1849

RESEARCH REPORT 16

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United States Department of the Interior, Oscar L. Chapman, *Secretary*

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CONTENTS

	Page
The Philippine Tiger Shark	2
Distribution and Methods of Capture	3
Relationship Between Total Length and Total Weight	3
Liver Weight and Total Body-Weight Relationship	5
Sexual Maturity	6
Fecundity	7
Food Habits	7
Literature Cited	10

NOTES ON THE BIOLOGY OF THE TIGER SHARK *(Galeocerdo arcticus)* FROM PHILIPPINE WATERS

Tiger sharks of the genus *Galeocèrdo*, known to be distributed generally throughout the warm seas of the world, are notorious for their omnivorous feeding habits. Most literature to date has dealt with this phenomenon. In addition, some size records have been reported from a few localities, and Sarangdhar (1943) has discussed the breeding habits of this shark in Indian waters; he has also described the female reproductive organs during gestation. No doubt the lack of information concerning this genus has been due chiefly to the difficulty of securing sufficient specimens, as the capture of a tiger shark calls for special gear in any region where a commercial shark fishery does not exist.

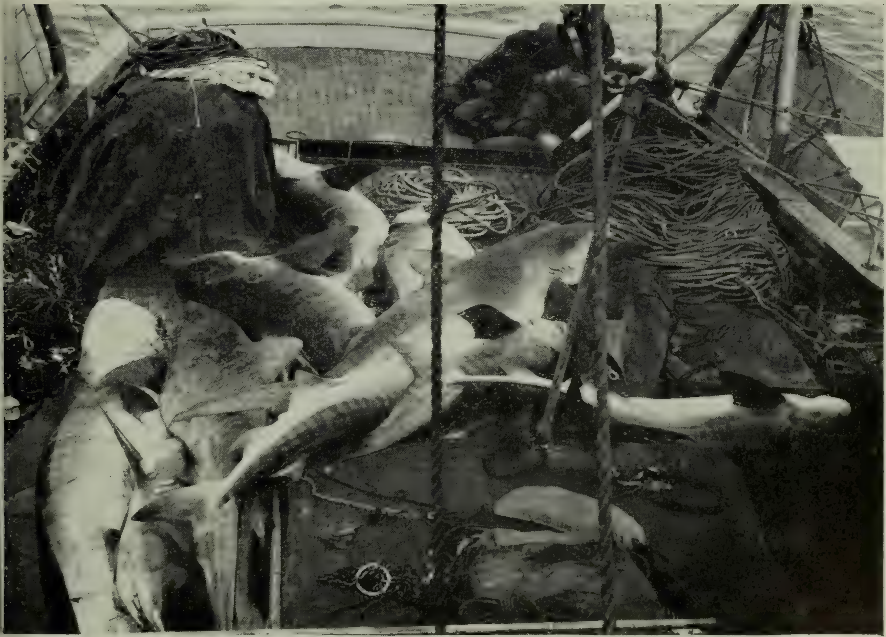

Figure 1.—A deckload of large tiger sharks from waters of the Sulu Archipelago.

While carrying out exploratory shark fishing in the Philippines with the experimental fishing vessel *Theodore N. Gill* of the Philippine Fishery Program of the United States Fish and Wildlife Service[1] during April and May 1948, the writer collected data on 43 specimens of *Galeocerdo arcticus* (Faber). This is perhaps the greatest number of these large sharks ever collected or studied in so short a period. The data thus secured form the basis for the observations presented in this publication.

The author acknowledges the invaluable assistance of the following staff members of the Philippine Fishery Program: Herbert E. Warfel, in charge of the biological and oceanographical investigations; Augustin Umali, ichthyologists and the officers and crew of the motor ship *Theodore N. Gill*, whose efforts resulted in the capture and landing of the specimens upon which the data are based.

THE PHILIPPINE TIGER SHARK

Inasmuch as there is a tendency to reduce the genus *Galeocerdo* to a monotypic status, as Gudger (1949) indicated, and as it is doubtful if large sharks are well represented in collections, the following description of Philippine specimens, based on adults 293 to 373 centimeters in total length, is included for taxonomic reference:

Color.—The dorsal surfaces of the body and flanks are a uniform gray, with darker tiger-like markings beginning slightly ahead of the first dorsal and extending posteriorly onto the upper caudal lobe, where they appear as spots. The ventral surface of head and body is white. The lateral limit of the gray color on the head extends from the tip of the snout above the nostril, runs parallel to the angle of the upper jaw, passes slightly below the eye, thence under the lower origin of the gill slits, and joins the leading edge of the pectoral fin at its base. The pectoral and ventral fins are gray above and white below.

Body proportions.—Viewed from above, the head is widest where the massive jaws form their angle and it tapers very gradually to the broadly rounded snout. The snout is short and dorsoventrally compressed; its length is almost equal to that of the preoral. The horizontal diameter of the eye is 3.8–4.8 in snout length and 1.9 in distance from orbit to spiracle. The preoral length is 2.3–3.1 in mouth width across the angles. The upper labial furrow extends before the eye about the diameter of the latter; the lower furrow is nearly one-half the length of the upper.

A mid-level lateral keel, originating on each side midway between the two dorsal fins, extends slightly beyond the caudal origin; it is most pronounced on the peduncle. A conspicuous median dorsal ridge originates on the head slightly behind the eyes and extends to the first dorsal. It appears shortly behind the base of the first dorsal and continues to within seven-eighths of the distance to the second dorsal, where it blends into a rather shallow furrow terminating at the base of the second dorsal fin.

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[1] A part of the Philippine Rehabilitation Program authorized by the Philippine Rehabilitation Act of 1946, Title 50 App., U. S. Code, 1789.

The length of the caudal measured from the precaudal pit to the tip of the upper lobe is 3.9–4.5 in total length. The second dorsal base is 2.3 in first dorsal base; the anal base 1.2 in second dorsal base; and the vertical height of second dorsal is 1.5 in vertical height of anal. The teeth are $\frac{20\text{–}23}{22\text{–}24}$.

DISTRIBUTION AND METHODS OF CAPTURE

To determine whether a profitable shark fishery might be developed, experimental fishing was conducted in the waters of the SuluArchipelago, from the southwestern tip of the island of Mindanao southwesterly to British North Borneo. Here, during April and May 1948, tiger sharks were abundant. The sharks were taken in shallow waters near land masses where the depth was about 30 fathoms and the bottom often uneven from the coral present. They were captured on baited long-lines suspended from the surface to a depth of 8 to 12 fathoms. Stout manila hemp line and heavy hooks on chain leaders were required to hold the powerful creatures.

There is no established tiger shark fishery in these islands. If an accidental capture occurs, the inhabitants use the flesh as food, generally preparing it by drying.

RELATIONSHIP BETWEEN TOTAL LENGTH AND TOTAL WEIGHT

The measurements and weights of the tiger sharks were recorded within a few hours after capture. The total length included the distance from the snout to the caudal tip. The weight was taken on a hanging beam scale suspended from the single fall on the boom of the vessel. A rope sling was placed near each end of the animal and the loops hooked on the scale. The single fall was then raised by winch until the animal cleared the deck. Thus the shark remained suspended in a nearly horizontal position and the scale could be easily manipulated.

The weight-length relationship was calculated by fitting the actual weights and lengths by the method of least squares employing the equation $Y=aX^b$ (Ripley 1946), expressed as $\log Y=\log a+b \log X$. Log Y represents the logarithm of the total weight in pounds and log X the logarithm of the total length in centimeters.

Based on 21 specimens, the weight of the females was found to increase as the length to the 3.4 power. These specimens ranged from 153 to 350 centimeters (5.0 to 11.5 feet) in total length and from 40 to 630 pounds in weight. These calculations did not include pregnant females as their weight was affected by the increased liver weight and the developing embryos or pups.

The weight of the males, based on 19 specimens, increased as the length to the 3.3 power. The male specimens ranged in total length from 211 to 367 centimeters (6.9 to 12.0 feet) and from 93 to 680 pounds in total weight. Maturity stages were not considered.

The results are shown graphically by the regression lines in figure 2. The data for the females are expressed by the formula log Y=

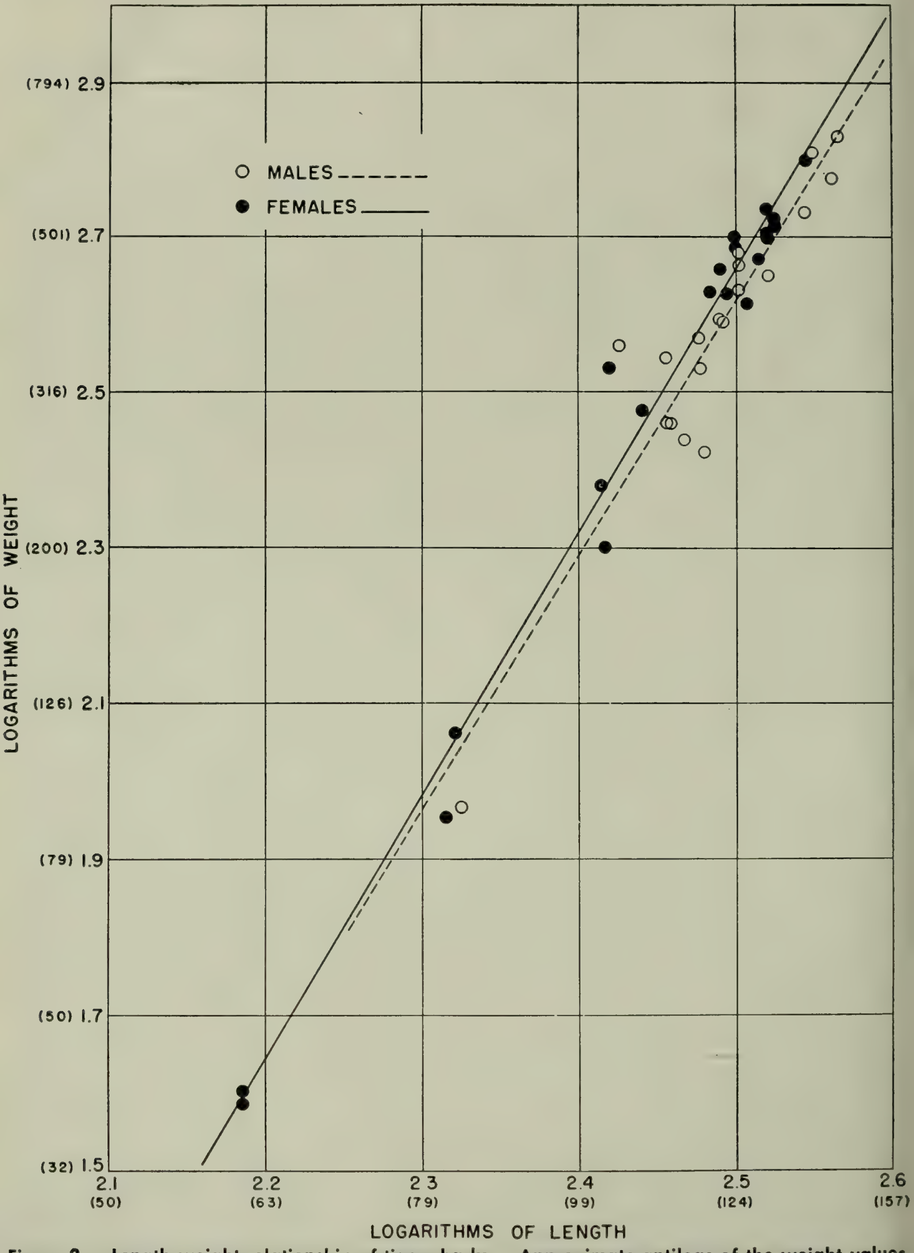

Figure 2.—Length-weight relationship of tiger sharks. Approximate antilogs of the weight values in pounds and of the length values in inches are included in parentheses for reference. The logarithms were originally in pounds and centimeters.

−5.73351+3.35609 log X; for the males by the formula log Y= −5.5054+3.25007 log X.

LIVER WEIGHT AND TOTAL BODY-WEIGHT RELATIONSHIP

The large tiger shark possesses a comparatively large liver in relation to the total body weight. The average liver weight—both sexes combined—expressed in percentage of total body weight for 30 sharks weighing more than 100 pounds, was 21 percent. Sharks of both sexes under 100 pounds in total body weight had a liver weight of only 6 percent.

In general, it was found that the liver weight of both sexes increased with the total body weight until a body weight of 240 pounds in females and 300 pounds in males was reached, when the maximum liver weight was achieved. This average held for females weighing up to 1,085 pounds and males to 680 pounds. No specimens larger than these were taken.

As only three pregnant females were encountered, the data are inadequate to show conclusively the effects of pregnancy on liver weight. The female with eggs developing in the uteri showed the highest percentage of liver weight to body weight (26 percent); whereas the two females with well-developed pups showed a decrease in liver weight to 20 and 21 percent, which was usual for females greater than 100 pounds in total body weight. These variations in percentage liver weights may indicate that at the onset and in the early stages of pregnancy the liver weight reaches its maximum weight and gradually falls as the gestation period advances. Figure 3 presents graphi-

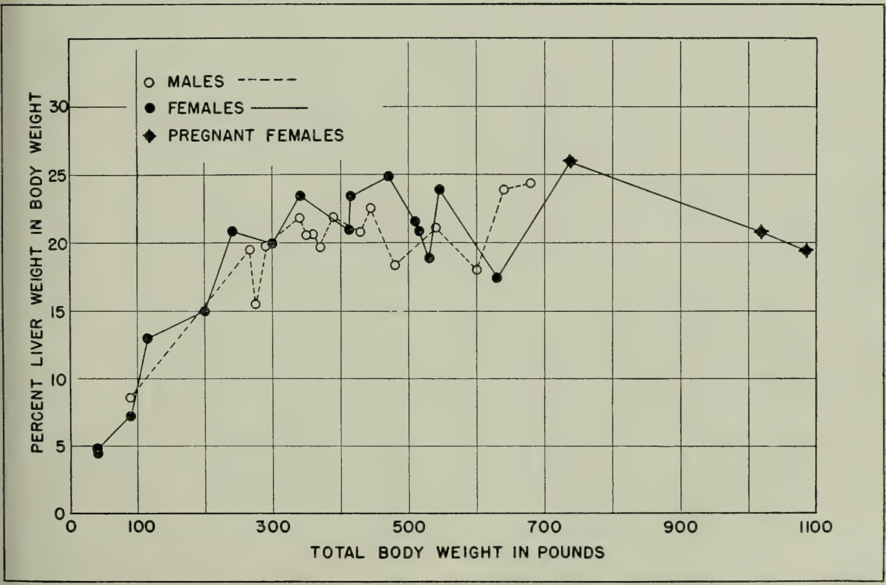

Figure 3.—Liver weight-body weight relationship of tiger sharks.

cally the liver weight-body weight relationship. The data are given in table 1.

SEXUAL MATURITY

A female shark was considered mature if large eggs were present in the ovaries or if the uteri contained fertilized eggs or embryos in any stage of development. The immature females had relatively small, flap-like ovaries composed principally of innumerable small ova of varied sizes.

Table 1.—Length, weight, weight of livers, and percentage relationship of tiger sharks captured during April and May 1948 in the waters of the Sulu Archipelago, Philippines

Sex	Total length in centimeters	Total length in feet	Total weight in pounds	Liver weight in pounds	Percentage liver weight in body weight
Female	153	5.02	40	2.2	5.8
Do	153	5.02	40	1.9	4.8
Do	206	6.76	90	6.7	7.3
Do	210	6.89	115	15.0	13.0
Do	259	8.50	240	50.0	20.8
Do	261	8.56	200	30.0	15.0
Do	262	8.60	340	80.0	23.5
Do	272	8.92	300	60.0	20.0
Do	305	10.00	425	-------	-------
Do	310	10.17	453	-------	-------
Do	312	10.24	415	97.0	23.4
Do	314	10.30	485	-------	-------
Do	315	10.33	485	-------	-------
Do	321	10.53	412	86.0	20.9
Do	327	10.73	470	117.0	24.9
Do	330	10.83	500	-------	-------
Do	330	10.83	545	130.0	23.9
Do	330	10.83	510	110.0	21.6
Do	334	10.96	530	100.0	18.9
Do	335	10.99	518	107.0	20.7
Do	350	11.48	630	113.0	17.9
Do	360	11.81	[1] 740	190.0	25.7
Female	373	12.24	[1] 1,085	212.0	19.5
Do	380	12.47	[1] 1,020	212.0	20.8
Male	211	6.92	93	8.1	8.6
Do	266	8.73	360	74.0	20.6
Do	285	9.35	290	-------	-------
Do	285	9.35	350	72.0	20.6
Do	286	9.38	290	57.0	19.7
Do	293	9.61	275	42.3	15.4
Do	299	9.81	370	73.0	19.7
Do	300	9.84	340	74.0	21.8
Do	302	9.91	265	51.5	19.4
Do	308	10.10	395	-------	-------
Do	310	10.17	390	85.0	21.8
Do	318	10.43	480	88.0	18.3
Do	318	10.43	480	-------	-------
Do	318	10.43	430	90.0	20.9
Do	332	10.89	445	100.0	22.5
Do	350	11.48	540	114.0	21.1
Do	353	11.58	640	153.0	23.9
Do	365	11.97	600	108.0	18.0
Do	367	12.04	680	165.0	24.3

[1] Pregnant.

The three female tiger sharks captured which were considered mature were pregnant and greater than 350 centimeters (11.5 feet) in total length. The remaining 21 females had small ovaries with numerous small eggs and were considered immature. On this basis it can be assumed that the female tiger shark in the Philippines reaches a length of about 350 centimeters (11.5 feet) at the time of first maturity. In Indian waters specimens 10 to 13 feet in length were found containing young (Sarangdhar, 1943).

The most positive criterion of sexual maturity in the males was the release of milt from the gonoduct when pressure was applied. However, in the majority of the specimens the enlarged testes were indicative of a mature male. The lack of sufficient range in sizes, particularly in the smaller specimens, made it impossible to determine the size of the males upon attaining first maturity. All those greater than 266 centimeters (8.73 feet) in total length were considered mature, and two of these contained milt.

FECUNDITY

The two females that bore pups were the heaviest sharks collected; one contained 41 young and the other 53. The latter also had one large undeveloped egg and one small embryo (12 cm.) in its uterine compartments. The egg showed no sign of development. A third female was 360 centimeters (11.8 feet) in length, weighed 740 pounds, and had 62 fertilized eggs (4–5 cm. diameter) in the uteri. Male pups were recognizable by the presence of the intromittent organ, figure 4. They were larger than the females and were predominant in both broods. Following are the data on the two groups:

Adult female, 373 cm. (12.2 ft.) total length; total weight, 1,085 pounds:

Data on group of 53 pups:	*Males*	*Females*
Size range [1]	237–338 mm. (9–13 inches).	224–334 mm. (8–13 inches).
Average total length.	291.6 mm.	282.4 mm.
Sex ratio	51.9 percent	48.1 percent

Adult female, 380 cm. (12.5 ft.) total length; total weight, 1,020 pounds:

Data on group of 41 pups:	*Males*	*Females*
Size range [2]	555–695 mm. (22–27 inches).	535–690 mm. (21–27 inches).
Average total length.	593.6 mm.	583.8 mm.
Sex ratio	51.2 percent	48.8 percent

---

[1] Measurements made after pups had been preserved in formalin for a few weeks.

[2] Measurements made shortly after pups were removed from the uteri.

The pups with their array of varied dark spots and bars against a light background differ pronouncedly in coloration from the parent (fig. 5). The only portion of the young that has the gray coloration so typical of the adult is the top of the head and the area directly above the gill slits. The middorsal ridge was emphasized from behind the first dorsal to the caudal by a solid wide line of dark pigment. The yolk sac and cord together stretched about half the total length of the body and the amount of thick, oily yolk material remaining varied from less than 50 to approximately 100 cubic centimeters, depending upon the size of the embryo.

FOOD HABITS

Three recent papers by Gudger (1948a, 1948b, 1949) summarize the knowledge to date of the food and feeding habits of the tiger shark in various areas of the Pacific, Indian, and Atlantic Oceans. Supplementary information is given here for the Philippine waters where this shark was found to be a scavenger with an unselective appetite. The present observations are based on the examination of 43 specimens, 21 of which had empty stomachs, either normally or by extruding the contents before being brought aboard the vessel. In many cases the everted esophagus was evident.

The hawksbill turtle, *Eretmochelys imbricata*,[2] was the common turtle found in the stomachs examined and the predominant source of food. From one stomach a ten-pound specimen was recovered intact, its only wound being a slight

---

[2] According to Taylor (1921, pp. 180–182). However, Stejneger and Barbour (1939, p. 169) call the hawksbill turtle from the Indian and Pacific Oceans *Eretmochelus squamata*, and reserve the name *E. imbricata* for the hawksbill turtle from American seas. Seale (1911, p. 291) refers the hawksbill turtle to *Chelone imbricata*.

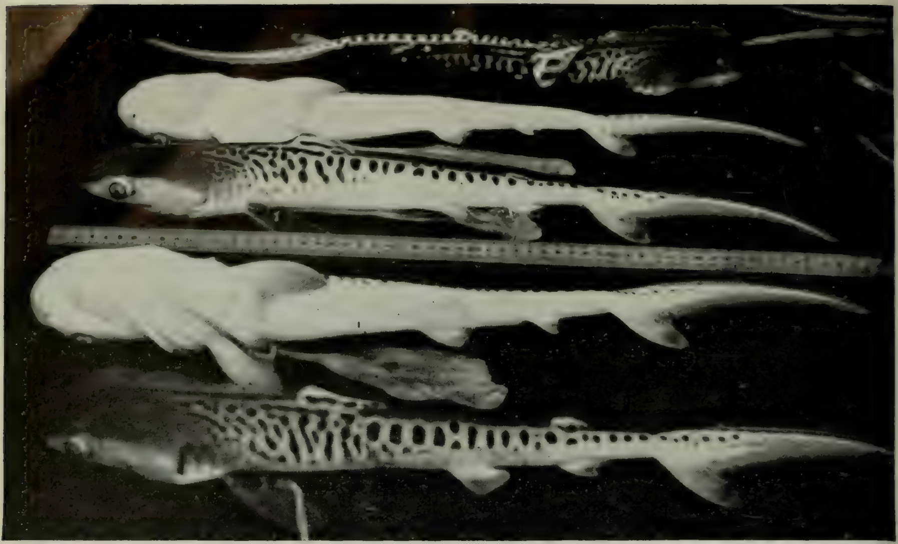

Figure 4.—Pups from a 12.5-foot female tiger shark. Note prominent markings, yolk sac, and point of attachment of the yolk sac cord. The claspers are visible on the male in the foreground.

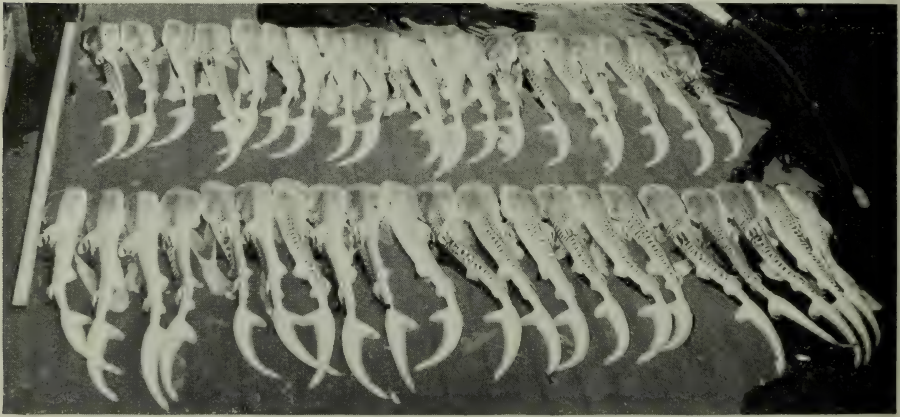

Figure 5.—Forty-one young tiger sharks on the deck of the fishing vessel. These were removed from a 12.5-foot female that weighed 1,020 pounds.

gash in the neck. Parts of the green turtle, *Chelonia mydas*,[3] were infrequent, appearing on only two occasions. In several stomachs all that remained to indicate turtle remains was a handful of fibrous intervertebral disks. In these cases the contents were classed as hawksbill since this species was identified most frequently.

The diversity of items in the tiger shark's diet and the frequency of their occurrence as revealed in the examination of the contents of 22 stomachs are shown in the following tabulation:

---

[3] According to Seale (1911, p. 292). Stejneger and Barbour (1939, p. 168) reserve the name *Chelonia mydas* for the green turtle of the Atlantic Ocean and Gulf of Mexico, and call the Pacific species *Chelonia agassizii*. Taylor (1921, p. 184), based on description of specimens from the Philippines, assigns the species the name *Chelonia japonica*.

Item:	*Frequency of occurrence*
Hawksbill turtle (*Eretmochelys imbricata*)	11
Unidentified fish remains	4
Hardtails (*Megalaspis cordyla*)	2
Green turtle (*Chelonia mydas*)	2
Squid	2
Crab	2
Feathers (origin unknown)	2
Sea snakes	2
Trigger fish (Monacanthidae)	1
Gurnard (Dactylopteridae)	1
Parrot Fish (Scaridae)	1
Shark flesh and liver	1
Eel	1
Black cat (*Felis domestica*)	1
Horse leg bone	1

The occurrence of the horse leg bone in one shark stomach may be explained by the fact that enroute to the fishing area horse meat was prepared for bait, and the bones thrown overboard. Possibly the shark had been following the vessel and remained long enough after swallowing the bone to take a baited hook.

During the fishing operations experiments were carried out to test he food preference of the species with horse meat, carabao meat, shark flesh, and fish flesh. However, no preference was found, and he shark appeared to take whatever bait was encountered first. From he standpoint of the bait most uitable for fishing, horse or carabao meat stayed on the hook the longest nd could be used more than once f kept refrigerated between operaions. Fish-flesh bait was most asily lost without a catch.

As the Sulu Archipelago is an rea of scattered small villages inhabitated by primitive people and is off the route of large cargo and passenger vessels, the shark's main source of food must come from the indigenous fishes and reptiles. This explains the absence in the stomachs of the refuse material commonly found in sharks in other localities where great amounts of debris are available. This, as well as the fact that the sharks often remained on the hooks for as many as twelve hours between setting the gear and hauling—giving ample time for the completion of the digestive processes—may account for the large number of empty stomachs found. Not to be overlooked as another cause of empty stomachs is the possibility that the struggling shark had disgorged its stomach contents.

The viciousness of this shark toward members of its own species was twice demonstrated in the course of the study. The first occurred when a rather small specimen was hauled aboard with its entire belly and viscera torn away. Later many chunks of shark liver were found in a large female caught on the same gear. Also, as this large shark was struggling alongside the vessel, the author saw her disgorge nearly a dozen large chunks of meat that quite evidently were torn from the belly of the smaller shark. No doubt, while the smaller shark was struggling on a hook the female attacked it, ate her fill, and not satisfied, took a baited hook. The second instance of cannibalism occurred some days later when a baited hook was brought aboard with only the remnant of a jaw remaining. The teeth provided positive identification of the jaw as that of a tiger shark and their size indicated a small specimen. Thus it appears that the large tiger sharks will attack smaller ones if the opportunity exists. This may explain why so few small specimens were captured, as they may avoid an area where larger individuals are abundant.

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GUIDE TO THE CLASSIFICATION OF FISHING GEAR IN THE PHILIPPINES

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RESEARCH REPORT 17

FISH AND WILDLIFE SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR

ABSTRACT

One of the serious handicaps in the administration and management of the fisheries of the Philippines has been the lack of standardized nomenclature for fishing gear. This publication attempts to solve the problem. It is divided into five parts: The first presents a basic classification of fishing gear; the second is a key by means of which fishing gear can be identified and new terms for fishing gear can be properly classified; the third defines and illustrates various types of fishing gear; the fourth is a tabular classification of local Filipino dialect names; and the fifth is a glossary including definitions of more than a thousand terms.

GUIDE TO THE CLASSIFICATION OF FISHING GEAR IN THE PHILIPPINES

By AGUSTIN F. UMALI, *Ichthyologist*

Illustrations by Silas G. Duran

March 3, 1849

RESEARCH REPORT 17

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United States Department of the Interior, Oscar L. Chapman, *Secretary*

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CONTENTS

Classification of the Gear.. 2

Part I. Basic Classification of Fishing Gear.................. 6

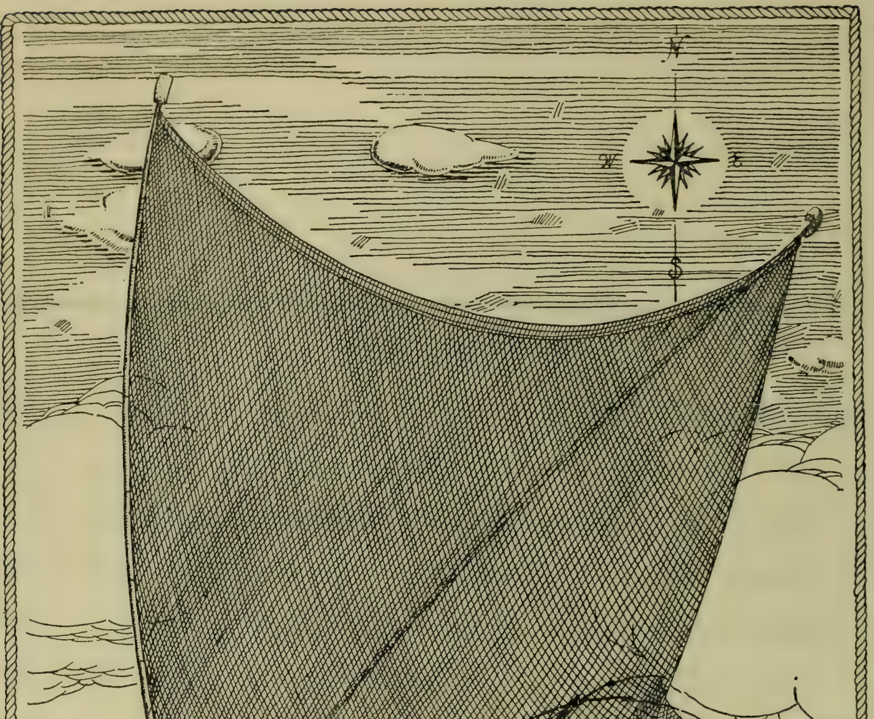
Part II. Key to the Identification of Classes of Fishing Gear.... 8

Part III. Definitions and Illustrations of Classes of Fishing Gear.. 12

Part IV. Classification of Philippine Fishing Gear.............. 70

Part V. Glossary of Philippine Fishing Gear.................. 97

Bibliography.. 163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GUIDE TO THE CLASSIFICATION OF FISHING GEAR IN THE PHILIPPINES

Attendant upon the existence of numerous and varied ingenious methods of taking fish and the prevalence of many dialects in the Republic of the Philippines is the confusion that results from the use of the diverse vernacular names of fishing appliances. This has hampered an understanding of the Philippine fisheries, and it is foreseeable that it would increase the problems that arise in attempts to manage fishery resources on a national scale. Specific examples of this are the conflicts registered during the Japanese regime in the Islands when the control of the fisheries was centralized in the National Government. With the promulgation at that time of Executive Order No. 271 by the defunct Philippine Executive Commission, a set of vernacular names was used as the basis for a schedule of tax rates for the use of fishing gear in Philippine waters. In several instances the same gear was charged different rates due to overlapping of dialect or local names, and many fishermen were sometimes unjustly penalized because of the absence of a standard classification.

It was principally with the aim of standardizing the gear nomenclature that the present study was undertaken, with the desire that the conflicts which arise from time to time may be settled equitably. Also, with the here proposed system of classification as the basis, it is hoped that problems arising from taxation on the use of the different gear in the Philippines, as provided for in the numerous municipal ordinances, can be readily adjusted. There is also hope that the work will facilitate the identification and distinction of fishing gear so that a newcomer in the Philippines will be able to recognize a particular apparatus by its local name without a speaking knowledge of the dialect. The final objective is to provide a basis for the compilation of fishery statistics for the Nation, based upon gear types operated.

This work is one of the results of the cooperative efforts of the Philippine Fishery Program of the United States Fish and Wildlife Service [1] and the Philippine Bureau of Fisheries. It was begun by the author in the latter organization in 1943, in the midst of war, but was temporarily suspended during the latter part of the Japanese occupation. After liberation, with the establishment in the Philippines, during 1947, of the headquarters and program of the Fish and Wildlife Service, the project was revived. Originally intended to be composed of only three parts, parts IV and V were appended in order to furnish a glossary of terms for Philippine fishing gear.

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[1] A part of the Philippine Rehabilitation Program authorized by the Philippine Rehabilitation Act of 1946, title 50, App. U. S. Code, sec. 1789.

The author is greatly indebted to the many fishermen in various parts of the Philippines, to students and faculty members of the Philippine Institute of Fisheries Technology (formerly the Philippine School of Fisheries), and to members of the staff of the Philippine Bureau of Fisheries who furnished information on the vernacular names.

To the American and Filipino members of the technical staff of the Philippine Fishery Program, Office of Foreign Activities, Fish and Wildlife Service, the author likewise is grateful for the many constructive criticisms and suggestions given during the preparation of the manuscript. The author is especially thankful to Herbert E. Warfel, Chief, Biological and Oceanographic Investigations, Philippine Fishery Program, for his review of the entire manuscript, and to Robert B. Fox of the Philippine National Museum for the many valuable suggestions in the ethnography of the Philippines and in the orthography of the dialect terms. The advice and encouragement of Hugh W. Terhune, Administrator, and Leroy R. Christey, Deputy Administrator, Philippine Fishery Program, have been most valuable.

CLASSIFICATION OF THE GEAR

In this attempt to classify the indigenous kinds of fishing gear used in the Philippines many difficulties were encountered. Some of these were almost impossible to settle reasonably, especially in cases of the same or closely-related gear having but slight differences in structure and method of operation. A specific instance is the sakag (Tagalog), a push net. When not provided with "runners" and operated as a set net with the aid of a scareline, it becomes a drive-in-net. Again, when this net is used on board watercraft it is fished by skimming the upper layers of water beyond wading depths, hence falls under the class of skimming nets.

Even placing gear in the more general divisions of textile and nontextile devices demanded many arbitrary judgments, as in the case of the deep-water fish corral. Essentially, the corral is a guiding barrier made of nontextile materials such as bamboo, rattan, diliman, and palma brava. In hauling the catch, however, a large "scoop seine," the gayad (Tagalog), a textile device, is employed. In this instance, a fish corral is classified under nontextile devices, taking into consideration the main gear rather than the accessory apparatus.

The scheme of classification followed is in the order of the developmental or, perhaps, evolutionary stages—the nontextile followed by the textile devices, and the unwebbed followed by the webbed gear.

The orthography adopted in writing the vernacular names follows closely that of the Tagalog dialect, one of the two official languages of the Republic of the Philippines. The usages in this language are deemed applicable to the different dialects except in recording the *v* and *f* sounds of local terms in the Ivatan and Ibanag dialects. In these cases the approximate English equivalents are used.

The Tagalog alphabet (ABAKADA) has five vowels (patinig) as follows: *a*, *e*, *i*, *o*, and *u* in which *e* and *i*, *o*, and *u* have almost the same values, respectively, and are interchangeable; and fifteen consonants (katinig) *b*, *k*, *d*, *g*, *h*, *l*, *m*, *n*, *nga*, *p*, *r*, *s*, *t*, *w*, and *y*, in which *y* is interchangeably used with *i*. Table 1 is a comparative list of some of the letters in the Spanish alphabet which are modified in the written Tagalog, together with examples of their usages as employed in this paper.

Table 1.—Comparison between Spanish and Tagalog alphabets with examples of usage

Spanish alphabet	Tagalog alphabet	Examples	
		Spanish script	Tagalog script
c	k	corona	korona.
	s	cerrada	serada.
ch	ts	Chabacano	Tsabakano.
	s	chinchorro	sinsoro.
f	p	Filipinas	Pilipinas.
j	h	Japones	Hapones.
ll	ly	cubcubillo	kubkubilyo.
	y	caballas	kabayas.
ñ	ny	Caviteño	Kabitenyo.
q	k	quitang	kitang.
rr	r	chinchorro	sinsoro.
v	b	Davaoeño	Dabawenyo.
x	s	xiir	siir.
	h	xiir	hiir.
z	s	alcabuz	alkabus.

The vernacular names used in the basic classification, part I, are in Tagalog. Some of these have been coined by the author, due to the absence of genuinely original names, and are presented for possible official adoption. All coined terms are marked with an asterisk.

The dialect groups follow very closely those of Beyer (1917). The abbreviations and their equivalents as employed in the present paper are listed in table 2, together with the regions where each is spoken. A dash between dialect names denotes combinations of two or more of them.

The work is divided into five parts. Part I contains the general classification of fishing gear which forms the basis of the entire study.

Some of the classes, although foreign to the Philippines, are incorporated in order to make the basic classification as complete as possible. Furthermore, it is anticipated that the development of the fishing industry will lead to the employment of some of this modern gear.

Part II is an artificial key devised for the identification of the classes of gear enumerated or outlined in part I and is intended as an instrument for the classification of fishing gear not as yet recorded in the present paper.

Table 2.—Dialects of the Philippines used in the present classification of the fishing gear

[Abbreviations used in the text and glossary are listed in the first column]

Abbreviations	Equivalents	Localities
Ak. Bis	Aklan Bisaya	Aklan regions, Panay Island.
Ban. Bis	Bantan Bisaya	Three towns in Romblon Province.
Bat. Tag	Batangas Tagalog	Batangas Province.
Bik	Bikol	Southern Luzon, including Catanduanes and Masbate Island.
Bik.-Tag	Bikol-Tagalog	Southern Tayabas Province.
Bis	Bisaya	Visayan Islands and northern Mindanao.
Bis.-Sp	Bisaya-Spanish	Visayan Islands.
Bis.-Tag	Bisaya-Tagalog	Do.
Buk	Bukidnon	Interior of northern Mindanao.
Kab	Kabitenyo (Tagalog-Spanish)	Cavite City, Luzon Island.
Kap	Kapampangan	Pampanga Province.
Kap.-Sp	Kapampangan-Spanish	Do.
Kuy	Kuyonon	Palawan Province.
Kuy.-Sp	Kuyonon-Spanish	Do.
Dab	Dabawenyo	Davao City, Mindanao Island.
Iban	Ibanag	Cagayan and Isabela Province.
Iban.-Sp	Ibanag-Spanish	Do.
Ig	Igorot	Various dialects in Mountain Province.
Il. Bis	Ilongo Bisaya	Western Visayas.
Ilk	Iloko	Northern Luzon.
Ilk.-Sp	Iloko-Spanish	Do.
Ivat	Ivatan	Batanes Group.
Mag	Magindanaw	Cotabato Province.
Mar	Maranaw	Lanao Province.
Moro	Moro	Various non-Christian dialects in Mindanao and Sulu.
Pal	Palanan (mixed Tagalog Negrito and Ibanag).	East coast of Isabela Province.
Pang	Pangasinan	Pangasinan Province.
Pang.-Sp	Pangasinan-Spanish	Do.
Pil	Pilipino	Philippines.
Pil.-Hap	Pilipino-Hapones	Philippines.
Pil.-Sp	Pilipino-Spanish	Do.
Sa	Samal	Coastal regions of Sulu Archipelago.
Sam. Bis	Samar Bisaya	Samar and Leyte Islands.
Sam. Bis.-Sp	Samar Bisaya-Spanish	Do.
Samb	Sambal	Zambales Province.
Seb. Bis	Sebu Bisaya	Eastern Visayas and northern Mindanao.
Sub	Subanon	Interior of Zamboanga Province.
Tag	Tagalog	Central Luzon, Tayabas, Mindoro, and Marinduque.
Tagb	Tagbanwa	Interior of Palawan.
Tagb.-Sp	Tagbanwa-Spanish	Tagalog regions.
Tsa	Tsabakano	Zamboanga City, Mindanao Island.
T. Sug	Taw Sug	Interior of Jolo.

Part III contains definitions of the classes of fishing gear and illustrations of typical examples of each.

Part IV is a classified list of vernacular names in actual usage in the islands for sundry fishing gear. These names are tabulated in the order of the Tagalog alphabet and intended for ready reference.

Part V contains definitions or short descriptions of the vernacular names tabulated in part IV and is intended to furnish more definite information on particular items of gear. In view of the complexity involved in listing complete vernacular synonyms of each gear name, the present work attempts to include only the most popularly known ones. Whenever available, the Tagalog synonym is stated.

Part I. BASIC CLASSIFICATION OF FISHING GEAR

NONTEXTILE DEVICES

A. Hand Instruments, exclusive of those made of textiles:

1. Snares------panilo
2. Miscellaneous hand instruments (gaffs, forks, hoes, spades, picks, scrapers, hooks, tongs, grabs)------panikwat
3. Spears------salapang
4. Harpoons------panibat or pamaril*
5. Rakes and dredges------pangahig or kalaykay
6. Scoops------panalok
7. Cover pots------salakab

B. Barriers and Traps, other than those made of textiles:

1. Barricades------pangharang*
2. Fish corrals------baklad
3. Fish pots------bubo
4. Miscellaneous set traps.
5. Fish shelters------bumbon

TEXTILE DEVICES

C. Lines:

1. Handlines------kawil
   - a. Simple handlines or drop lines------kawil
   - b. Multiple handlines------kawil-moderno*
   - c. Jiggers------hila-hila
   - d. Pole and lines------binwit or biwas
   - e. Troll lines (trolling including kite lines)------sibid-sibid or pahila
2. Longlines------kitang
   - a. Set longlines------palagiang-kitang*
   - b. Drift longlines------kitang-paanod*

D. Nets:

1. Impounding nets:
   - a. Set impounding nets:
     - (1) Filter nets------dayakus
     - (2) Hoop nets------bukatot-na-lambat
     - (3) Fyke nets------panalang-dagat*
     - (4) Trap nets------baklad-na-lambat*
   - b. Mobile impounding nets:
     - (1) Lift nets:
       - (a) Dip nets------panadiyok
       - (b) Push nets------sakag
       - (c) Skimming nets------anod-sulong*
       - (d) Crab lift nets------bintol
       - (e) Cover nets------panaklob
       - (f) Cast nets------dala
       - (g) Drive-in-nets------kulokutok
       - (h) Lever nets------salambaw
       - (i) Blanket nets------paduyan
       - (j) Bag nets------basnig

---

* Coined name.

TEXTILE DEVICES—Continued

D. NETS—Continued	
(2) Pull nets:	
(a) Seines	pukot
(1′) Drag seines or long haul seines (shore or beach seines)	salap or sinsoro
(2′) Reef seines	ligkop
(3′) Tuck seines	pukot-laot
(a′) Round haul seines	sapyaw
(b′) Purse seines	kubkob
(c′) Ring nets	talakop
(d′) Scoop seines	gayad
(4′) Stop seines	pangulong
(b) Dredge nets and shank nets	kaladkad
(c) Trawls	taksay
(1′) Danish trawls	taksay-dinamarka*
(2′) Irish trawls	taksay-irlanda*
(3′) Japanese trawls	utase
(4′) Spanish trawls	paransela, parehas, or taksay-kastila*
(5′) Beam trawls	taksay-aldaki*
(6′) Otter trawls	taksay-oter*
(7′) V–D trawls	taksay–B–D*
2. Entangling nets:	
a. Gill nets	paningahan
(1) Set gill nets (anchored or staked; floating or submerged)	palagiang-paningahan
(2) Drift nets	panti or paanod
(3) Encircling gill nets	bating or halang
b. Trammel nets	trasmalyo*

---

*Coined name.

Part II. KEY TO THE IDENTIFICATION OF CLASSES OF FISHING GEAR

NONTEXTILE DEVICES

(Fishing apparatus essentially made of materials other than textile)

a. Movable instruments manipulated by one man----------HAND INSTRUMENTS

b. Simple devices without webbings or mattings.

c. Running noose usually at the end of pole or shaft--------snares (panilo)

cc. Metal blade at end of handle, pole, or shaft.

d. Curve-tipped blades, usually barbless------------------------------ miscellaneous hand instruments (panikwat)

dd. Straight-tipped blades, usually barbed.

e. Blades not detachable from shaft or handle--------spears (salapang)

ee. Blades detachable from shaft or handle-------------------------- harpoons (panibat or pamaril*)

bb. More or less complicated devices with webbings or mattings.

c. Pulled instruments; capture effected by raking or scratching----------- rakes and dredges (pangahig)

cc. Dipped instruments; capture effected either by brailing or entrapping.

d. Opening uppermost and fished by dipping------------scoops (panalok)

dd. Opening lowermost and fished by covering------cover pots (salakab)

aa. Fixed or stationary gear usually operated by several men----------------- BARRIERS AND TRAPS

b. Barriers that intercept natural movements of fish.

c. Complete barriers----------------------------barricades (pangharang*)

cc. Guiding barriers------------------------------------fish corrals (baklad)

bb. Traps that entice fish by employment of strong smelling baits or by the simulation of natural living conditions, hiding places or nesting facilities.

c. Regular receptacles

d. Capture effected by the presence of nonreturn valves------------- fish pots (bubo)

dd. Capture effected by the presence of trap doors or devices other than nonreturn valves----------------------------miscellaneous set traps

cc. Anchored bunches of twigs, bushes, weeds, piles of poles, etc., in the form of shelters--------------------------------fish shelters (bumbon)

TEXTILE DEVICES

(Fishing apparatus principally made of textiles)

a. Made of simple, nonknitted twines-----------------------------------LINES

b. Require constant attention----------------------------handlines (kawil)

c. Still fishing in a vertical or somewhat vertical manner.

d. Line not attached to a pole.

e. A single hook or only two hooks attached to the line------------- simple handline or drop lines (kawil)

---

* Coined name.

TEXTILE DEVICES—Continued

a. Made of simple, nonknitted twines—Continued

ee. A small series of hooks usually attached by spreaders to the mainline at regular intervals---------multiple handlines (kawil-moderno*)

dd. Line usually attached to a pole or handle.

e. Single hook attached to a pole and fished by "striking"----------- pole and line (binwit or biwas)

ee. Several hooks grouped together in one or more bunches, and fished by "foul-hooking"-------------------------jiggers (hila-hila)

cc. Fished in motion in a horizontal manner---troll lines (sibid-sibid or pahila).

bb. Require only periodical attention--------------------longlines (kitang)

c. Anchored, not free to drift with the current------------------------- set longlines (palagiang-kitang*)

cc. Not anchored, free to drift with the current------------------------ drift longlines (kitang-paanod*)

aa. Made of webbed textile or knitted twines---------------------------NETS

b. Capture effected by impounding.

c. Cannot be freely moved within a short interval of time--------------- set impounding nets

d. Complete or almost complete barriers set in flowing water and catch effected by straining.

e. Conical bag nets not constructed over hoops and devoid of nonreturn valves------------------------------------filter nets (dayakus)

ee. Funnel-like bag nets constructed over circular hoops with nonreturn valves.

f. Without wings------------------hoop nets (bukatot-na-lambat)

ff. With two wings-------------------fyke nets (panalang-dagat*)

dd. Guiding barriers, a portion of which is tri-dimensional or bag-like, set in comparatively still waters and catch fish by guiding them into the enclosure-------trap nets and pound nets (baklad-na-lambat*)

cc. Can be freely moved within a short interval of time----------------- mobile impounding nets

d. Capture effected by a vertical lifting motion--------------lift net

e. Operated by one man.

f. With handle.

g. Merely scooped--------------------------dip nets (panalok)

gg. Pushed and lifted.

h. Used in shallow water by wading--------push nets (sakag)

hh. Used in deeper water from a watercraft----------------- skimming nets (anod-sulong*)

ff. Without handle and usually retrieved by means of a line (except in cover nets).

g. Opening uppermost to dip or scoop, and lifted, with or without the use of bait----------------------crab lift nets (bintol)

gg. Opening lowermost to cover fish.

h. Circularly framed nets employed as an accessory gear to cover enticed fish-------------------- cover nets (sukob)

hh. Unframed, conelike net thrown or cast to cover fish in open water--------------------------------cast nets (dala)

ee. Operated by several men.

f. Operated with the aid of a scareline-----drive-in-nets (kulokutok)

ff. Operated without the aid of a scareline.

---

* Coined name.

TEXTILE DEVICES—Continued

aa. Made of webbed textile or knitted twines—Continued

g. Curtainlike rectangular nets.

h. Somewhat rigidly framed device, the capture of fish effected by a dipping action on a leverlike mechanism------------ lever nets (salambaw)

hh. Loosely framed device, the capture of fish effected by a scooping action made by lifting the weighted side of the net from a watercraft or platform without the employment of a leverlike mechanism---------blanket nets (paduyan)

gg. Bag-like conical (saclike) or cubical (boxlike) net----------- bag nets (basnig)

dd. Capture effected by horizontal pulling or dragging motion---pull nets

e. Curtainlike nets with or without bag----------------seines (pukot)

f. Composed of only one seine.

g. Hauled toward the shore or bank.

h. Operated on smooth, gradually sloping beaches------------- drag seines (salap or sinsoro)

hh. Operated on reefs----------------------reef seines (ligkop)

gg. Hauled on board one or more boats away from the shore------ tuck seines (pukot-laot)

h. Without pursing device----------round haul seines (sapyaw)

hh. With pursing device.

i. Bunt toward one end---------------purse seines (kubkob)

ii. Bunt at the center flanked by the two wings.

j. Hauled on board one or two boats----ring nets (talakop)

jj. Hauled on a platform in fish corrals-scoop seines (gayad)

ff. Composed of more than one seine--------stop seines (pangulong)

ee. Funnel-shaped, baglike, cylindrical, or conical nets.

f. With raking device at lower edge of rigid opening---------------- dredge nets and shank nets (kalakad)

ff. Without raking device at lower edge of flexible mouth, the latter controlled by some forms of opening devices----trawls (taksay)

g. Operated from only one boat.

h. Wings generally long with vertical run of meshes.

i. Very long towing warps used as opening device------------ Danish trawls (taksay-dinamarka*)

ii. Wooden or banboo poles or beams used as opening device.

j. Beams or booms (outriggers) stepped to the boat employed as opening device---------Irish trawl (taksay-irlanda*)

jj. Wooden or bamboo beams secured to the main bridle used as opening device---------Japanese trawl (utase)

hh. Wings generally short with horizontal run of meshes.

i. Wooden beam attached to trawl heads keeps mouth open-- beam trawl (taksay-aldaki*)

ii. Otter boards or doors keep mouth open.

j. Doors attached near the tip of the wings---------------- otter trawl (taksay-oter*)

jj. Doors attached some distance from wings-------------- V–D trawls (taksay B–D*)

gg. Operated from two boats------Spanish trawl (taksay-kastila*)

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* Coined name.

TEXTILE DEVICES—Continued

bb. Capture effected by gilling or enmeshing.
  c. Composed of only one net------------------------gill nets (paningahan)
    d. Fished in a straight line.
      e. Anchored, not free to drift with the wind and/or tide-------------- set gill nets (palagiang-paningahan)
      ee. Not anchored, free to drift with the wind and/or tide------------- drift nets (pante or paanod)
    dd. Fished in a circle or in an arc of a circle--------------------------- encircling gill net (bating or halang)
  cc. Composed of more than one net------------trammel nets (trasmalyo*)

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* Coined name.

Part III. DEFINITIONS OF CLASSES OF FISHING GEAR[2]

A. Hand Instruments.—Instruments exclusive of those made of textile, which are manipulated by a single man.

1. **Snares.**—A running noose at the end of a pole or shaft (fig. 1).
2. **Miscellaneous hand instruments.**—Instruments consisting of a handle or shaft bearing a barbed or barbless, pointed or blunt metal blade at the curved tip, such as gaffs, forks, hoes, picks, scrapes, spades, hooks, tongs, and grabs (fig. 2).
3. **Spears.**—Instruments provided with pointed, barbed or barbless blades at the straight tip which are not detachable from the handle or shaft, and generally thrown by hand although sometimes shot from a gun or bowlike device (fig. 3).
4. **Harpoons.**—Instruments provided with pointed, barbed blades which are detachable from the handle or shaft, and either thrown by hand or discharged from a gun (fig. 4).
5. **Rakes and dredges.**—Pulled instruments made of nontextile webs or splints in which the capture of fish is effected by the raking or scratching action on the bottom of rivers, lakes, and seas (fig. 5).
6. **Scoops.**—Lifted instruments made of nontextile webs in which the capture of fish is effected by a brailing or dipping action (fig. 6).
7. **Cover pots.**—Entrapping devices devoid of a nonreturn valve with the opening lowermost to cover fish (fig. 7).

B. Barriers and Traps.—All types of gear exclusive of those made of textile which are either temporarily or permanently fixed to the bottom, and in which fish are caught in an area they have entered after having been led, enticed, or attracted into it.

1. **Barricades.**—Complete barriers principally made of various nontextile materials which prevent the escape of fish from a certain natural area which they have voluntarily entered after having been intercepted in their natural course of migration or movement in their search for food, hiding places, and breeding facilities (fig. 8).
2. **Fish corrals.**—Guiding barriers constructed of bamboo, brush, or chicken wire, which are set by means of regularly-spaced stakes or posts in tidal waters or along the natural paths of fish, and which are of such shapes as to direct the voluntary movements of fish into a desired area (fig. 9).
3. **Fish pots.**—Usually baited enticing devices made of bamboo, rattan or chicken wire in the form of regular receptacles with a nonreturn valve which provides easy entrance but difficult exit (fig. 10).
4. **Miscellaneous set traps.**—Other set traps or enticing devices which are regular receptacles, exclusive of those made of nets, which prevent the escape of fish by means of trap doors or devices other than nonreturn valves (fig. 11).
5. **Fish shelters.**—Anchored bunches of twigs, bushes, weeds, piles of poles, etc., which afford refuge for fish, and from whence the fish are captured by varied accessory devices operated in different ways (fig. 12).

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[2] Fishing gear is here meant to include all apparatus and implements used in catching fish exclusive of the boat or boats employed in the fishing operations. These definitions are, in the majority of cases, applicable only to those used in the Philippines.

C. LINES.—Devices consisting of baited hooks attached to a line or lines which fish on the principle that fish fall victims to baits.

1. **Handlines.**—Long simple lines with only a small series of baited hooks requiring constant attention.
   - a. **Simple handlines or drop lines.**—A single vertical line carrying one or two barbed hooks and worked by simply dropping it into the water and waiting for a fish to bite (fig. 13).
   - b. **Multiple handlines.**—A single vertical line with a small series of barbed hooks attached to it by "spreaders" at regular intervals (fig. 14).
   - c. **Jiggers.**—Lines, each bearing a multiple-hooked device, which are worked by jerking up and down under a bright light, making the hooked lures attractive to squids (fig. 15).
   - d. **Pole and lines.**—Handlines attached to a pole or poles and used with acceptable baits of all kinds. Jack pole fishing for tuna and bonito, using live bait, is the most highly commercial form of this gear (fig. 16).
   - e. **Troll lines.**—Long handlines, fished horizontally with a hook or hooks at the free end, baited with either a natural bait or an artificial lure, and the whole arrangement drawn or towed behind a boat underway (fig. 17).
2. **Longlines.**—Extremely long lines with a large series of baited hooks, either set or drifting, and requiring only periodical attention at more or less fixed intervals of time.
   - a. **Set longlines.**—Longlines anchored or in some way attached to the bottom so that they are not free to move with the current (fig. 18).
     - (1) Surface or floating set.
     - (2) Oblique, transverse, or diagonal set.
     - (3) Bottom or submerged set.
   - b. **Drift longlines.**—Longlines without a fixed attachment to the bottom which are free to drift with the current or tide (fig. 19).
     - (1) Floating set.
     - (2) Submerged set.

D. NETS.—All fishing gear principally made of woven or knitted fabrics with openings or meshes of uniform, or almost uniform, sizes, at least in the individual parts of the net.

1. **Impounding nets.**—Nets in which the capture is effected by a process of confining fish.
   - a. **Set impounding nets.**—Impounding nets which are anchored or in some way permanently attached to the bottom so that they cannot be freely moved from place to place within a short interval of time.
     - (1) **Filter nets.**—Fixed, usually conical, bag nets without nonreturn valves, set in flowing water and the capture effected by straining (fig. 20).
     - (2) **Hoop nets.**—Funnel-like bag nets constructed over circular hoops, having nonreturn valves but no wings (fig. 21).
     - (3) **Fyke nets.**—Set nets consisting of a series of definitely funnel-shaped entrances, as in hoop nets, which lead into a closed sac, there forming a trap with small openings from which exit is difficult. These differ from hoop nets only in the presence of wings (fig. 22).
     - (4) **Trap nets and pound nets.**—Fixed impounding nets supported by either stakes (usually wooden) or held in place and maintained in form by a combination of floats or buoys and weights or anchors (fig. 23).

D. Nets—Continued

- b. **Mobile impounding nets.**—Nets not in any way permanently attached to the bottom which can be readily transferred from place to place within a short interval of time. These will not fish unless moved through the water.
  - (1) **Lift nets.**—Nets in which the capture is effected by a vertical lifting motion of the gear (fig. 24).
    - (a) **Dip nets.**—Variously shaped and framed small bag nets, used entirely by hand or partly by mechanical power, in which fish are captured by a scooping motion (fig. 25).
    - (b) **Push nets.**—Triangularly-framed, collapsible nets operated by one man and the capture effected by a forward, horizontal (pushing) motion along the bottom of shallow waters within wading depths (fig. 26).
    - (c) **Skimming nets.**—Lifted push nets operated in deeper waters from a small watercraft, raft, or banca, using a skimming motion while drifting with the vessel (fig. 27).
    - (d) **Crab lift nets.**—Framed, shallow lift nets which are baited, sunk to the bottom by lines and weights, and, once in a while, hauled suddenly to the surface, thus requiring only periodical attention (fig. 28).
    - (e) **Cover nets.**—Somewhat conical accessory nets with a circular, rigidly-framed mouth, this opening being lowermost to cover fish previously enticed into other contraptions (fig. 29).
    - (f) **Cast nets.**—Conical nets usually operated by one man (except when used in deeper water from a boat) which are thrown to cover the fish. Heavily-weighted around the base, each is provided with a retrieving line attached to the apical portion (fig. 30).
    - (g) **Drive-in-nets.**—Various forms of framed or unframed lift nets operated with a scareline (fig. 31).
    - (h) **Lever nets.**—Large, rigidly-framed lift nets mounted on a bamboo raft and fished by an ordinary dipping motion of a leverlike arrangement (fig. 32).
    - (i) **Blanket nets.**—Lift nets operated with the aid of light or chummed bait, having the float line attached to or suspended from an outrigger of the boat, or to a series of whole-length bamboo floats. Lines attached to the leaded side of the net are used to haul in this gear from the bottom, and these can be drawn on deck by hand or by mechanical power. The entire gear is hauled in with a partly-pulling and partly-lifting motion (fig. 33).
    - (j) **Bag nets.**—Conical or cubical bag nets operated with the aid of light during the dark of the moon, and the capture effected by a lifting motion (fig. 34).
  - (2) **Pull or drag nets.**—Nets in which the capture of the fish is effected by a horizontal pulling or dragging motion of the gear.
    - (a) **Seines.**—Nets consisting of a bunt or bag, flanked on each side by quarters and wings. The apparatus is shot in such a position as to enclose a definite body of water containing a shoal or school of fish, thereby effecting the localization of the latter, and then hauled toward the shore or to a vessel.
      - (1′) **Drag seines.**—Otherwise known as shore, ground, or beach seines these are operated on smooth, gradually shelving shores and are always hauled toward the shore or river bank (fig. 35).

D. Nets—Continued

(2′) **Reef seines.**—Drag seines operated on reefs or rough grounds having the corkline submerged and the leadline continuously freed from snags by divers (fig. 36).

(3′) **Tuck seines.**—Seines fished out in the sea with the hauling always done from on board one or more boats.

(a′) **Round haul seine.**—Seines payed out in a circle or an arc of a circle, thereby surrounding the school; ends of the wings then are pulled on board one or more boats until the catch is concentrated in the bag or bunt, from whence it is brailed out (fig. 37).

(b′) **Purse seines.**—Tuck seines having the bunt or landing piece at one end, and the whole net provided with a pursing device. The latter consists of a series of purse rings attached to the footrope by straps or ring bridles. A pursing line rove through the rings closes the bottom of the seine when pulled, thereby forming a trap or purse (fig. 38).

(c′) **Ring nets.**—Tuck seines which, in structure, combine the features of the round haul seine (which has the bunt at the center and is flanked by two wings) and the purse seine (which has a regular pursing device) (fig. 39).

(d′) **Scoop seines.**—A small purse seine which is employed as an accessory gear in hauling the catch direct from the large semicircular enclosure of deep-water fish corrals, the latter devoid of a collecting pound or crib (fig. 40).

(4′) **Stop seines.**—A seine composed of two separate parts: the seine proper and the stop seine. The first surrounds and impounds the school, and the latter is shot inside the seine proper to collect the catch (fig. 41).

(b) **Dredge nets and shank nets.**—Bag nets in which the mouth or opening consists of firm, solid structures of bamboo, wood, or iron, having a raking device at the lower edge and collecting the catch in a net trailed from behind (fig. 42).

(c) **Trawls.**—Nets made in the form of a conical bag with the mouth kept open by various devices and the entire gear towed, trailed, or trawled, usually on the bottom of the sea, to capture submerged species that naturally keep at or near the bottom.

(1′) **Danish trawls.**—Otherwise known as Danish seines, these trawls have comparatively long wings with extremely long ropes used to keep the mouth open (fig. 43).

(2′) **Irish trawls.**—Long-winged trawls in which wooden or bamboo outriggers or booms stepped on board the boat are used in spreading the wings apart (fig. 44).

(3′) **Japanese trawls.**—Long-winged trawls having detachable bamboo or wooden beams attached to the main bridle a short distance from the tip of the wings (fig. 45).

(4′) **Spanish trawls.**—Otherwise known as "paranzella" or "parejas", these trawls have comparatively long wings. A pair of boats, traveling in parallel direction at a fixed and constant distance from each other, is used in the operation to insure the opening of the net (fig. 46).

(5′) **Beam trawls.**—Trawls provided with comparatively very short wings and having a wooden beam attached to the tip of the wings by trawl heads in order to keep open the mouth of the bag (fig. 47).

D. NETS—Continued

(6′) **Otter trawls.**—Short-winged trawls having two otter boards or doors acting as kites to keep open the mouth of the net (fig. 48).

(7′) **V-D trawls.**—A type of otter trawl designed by Vigneron and Dahl which has the otter doors attached some distance from the tip of the wings, thereby increasing the effective fishing width of the net (fig. 49).

2. **Entangling nets.**—Nets which effect the capture of fish by gilling or entrapping (trammeling).

a. **Gill nets.**—Curtainlike nets in which the capture of fish is effected by the actual meshes of the net.

(1) **Set gill nets.**—Gill nets anchored or in some way attached to the bottom so that they are not free to move with the water current (fig. 50).

(2) **Drift nets.**—Gill nets usually fixed to boats or other craft and are free to move with the wind or tide (fig. 51).

(3) **Encircling gill nets.**—Gill nets payed out in a circle or an arc of a circle, and the gilling process hastened by frightening the fish with various devices (fig. 52).

b. **Trammel nets.**—An entangling net consisting of two or three layers , the inner or middle one (fine-meshed) being slack, and the outer (coarse-meshed) being stretched taut. Capture is effected by tying up or retaining the fish in pocketlike spaces created by the nets while the fish is trying to escape. These are most often used as a drift net in rivers and as a set (gill) net in the ocean (fig. 53).

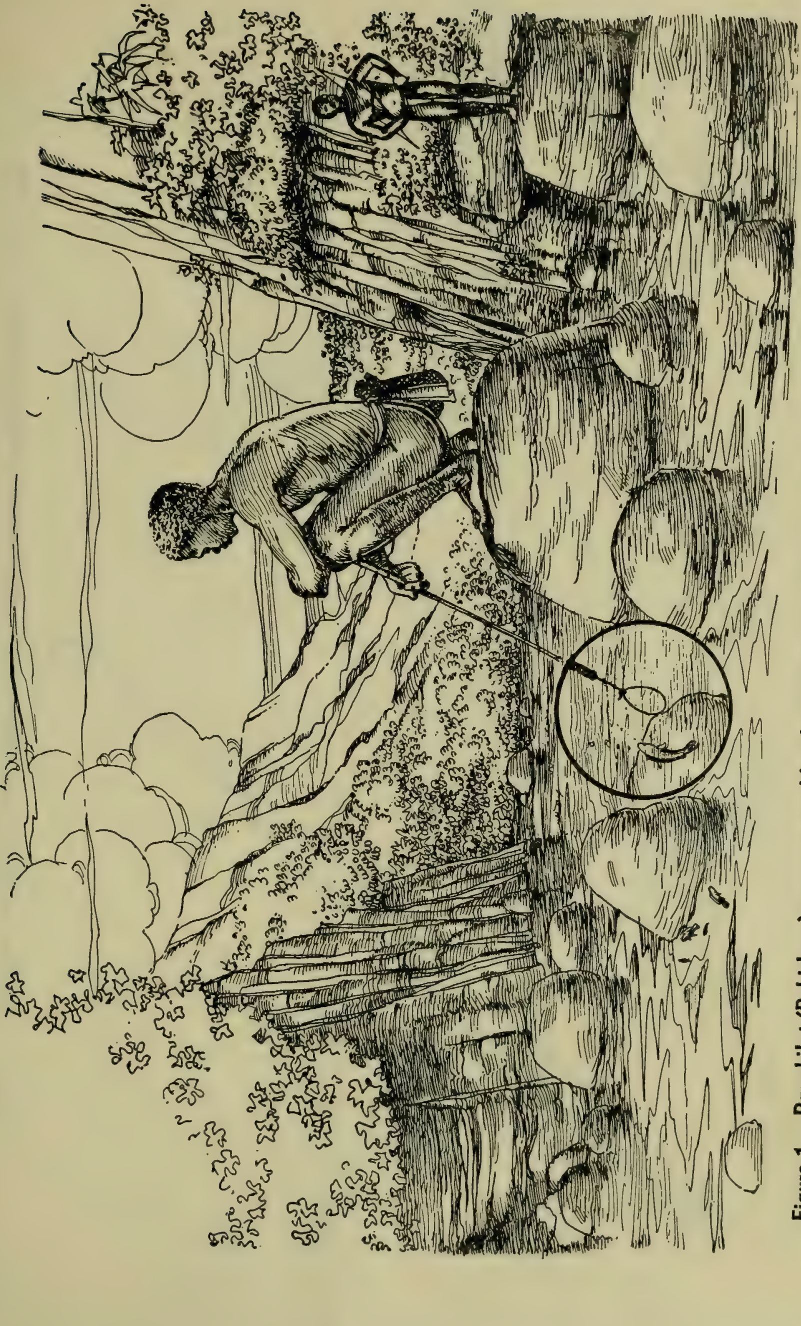

Figure 1.—Panghilot (Bukidnon), a snare used by the mountain peoples in northern Mindanao for catching anga, a goby.

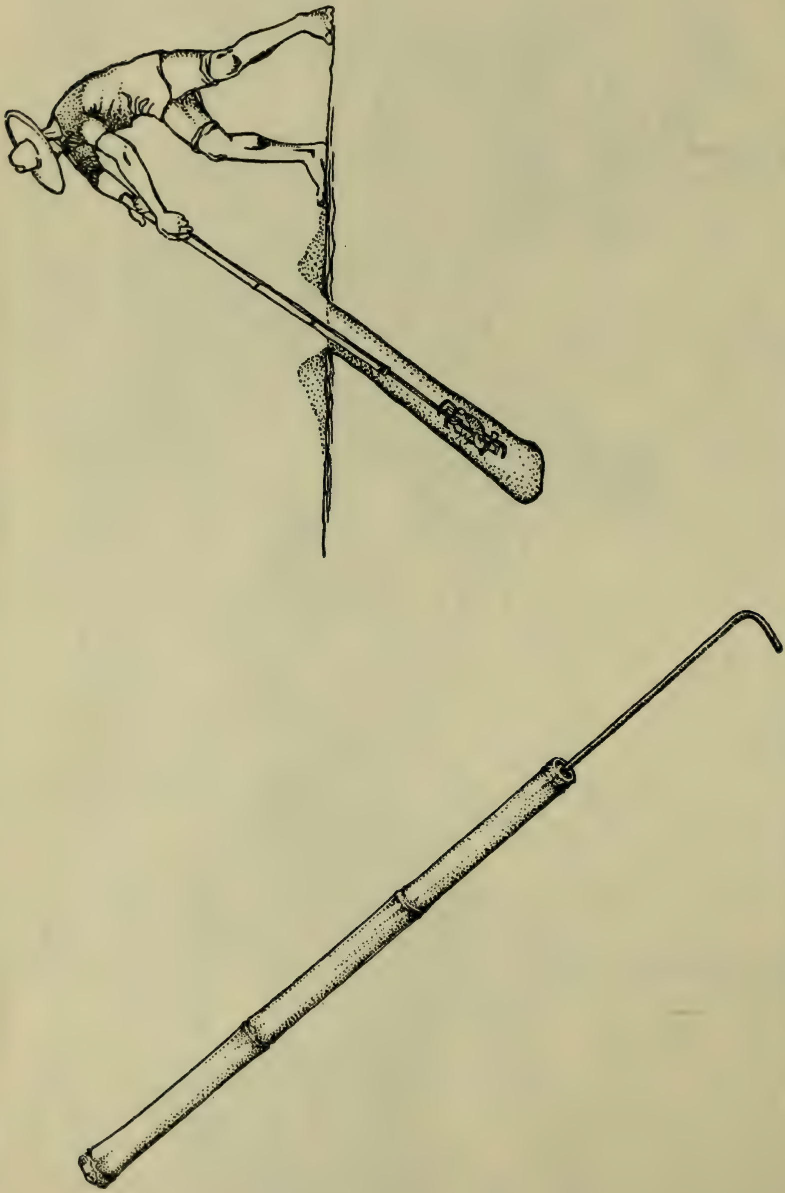

Figure 2.—Panukot (Tagalog), a crab hook used in central Luzon for catching alimango, a land crab.

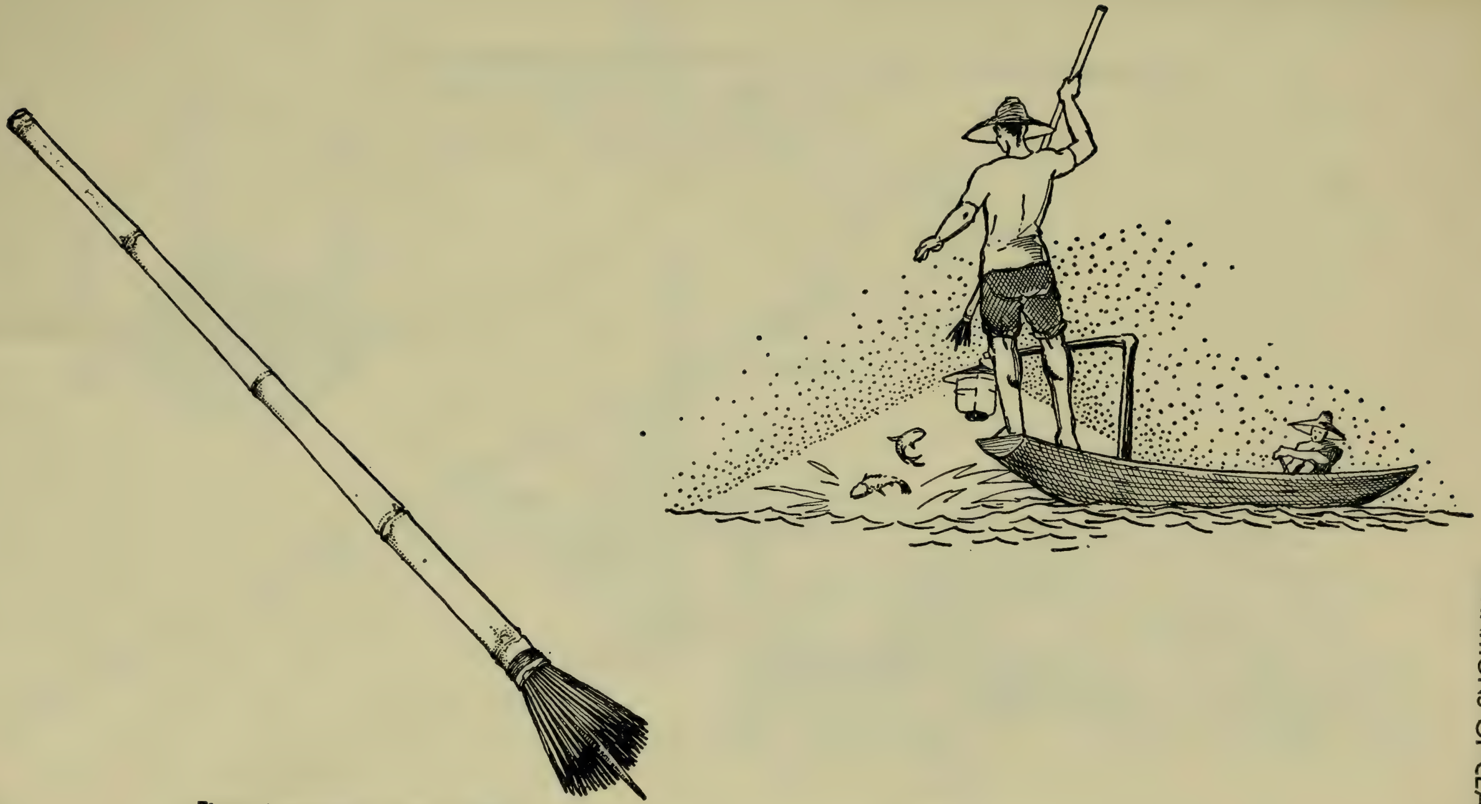

Figure 3.—Salubang (Aklan Bisaya), a spear used in Antique Province for catching fish and marine turtles.

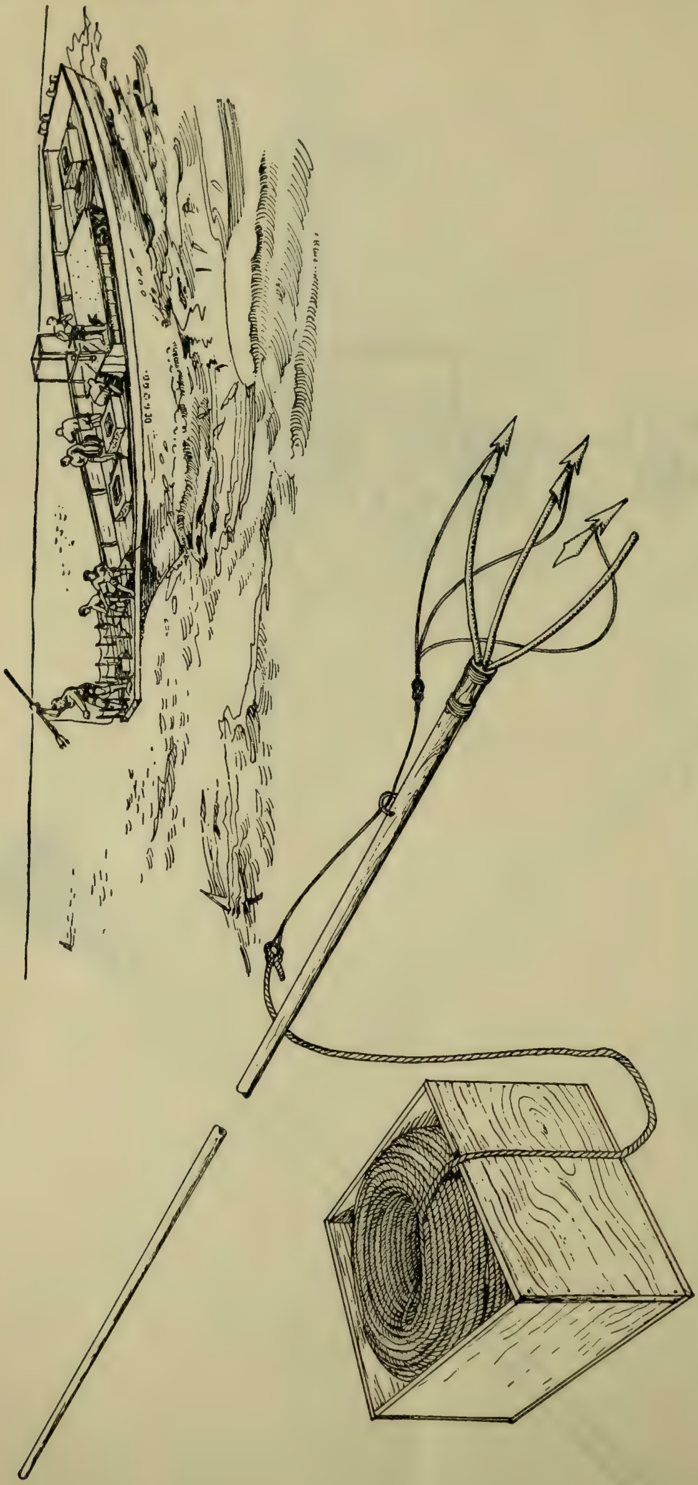

Figure 4.—Harpoon for large pelagic fishes such as sharks, sailfishes, spearfishes, and swordfishes.

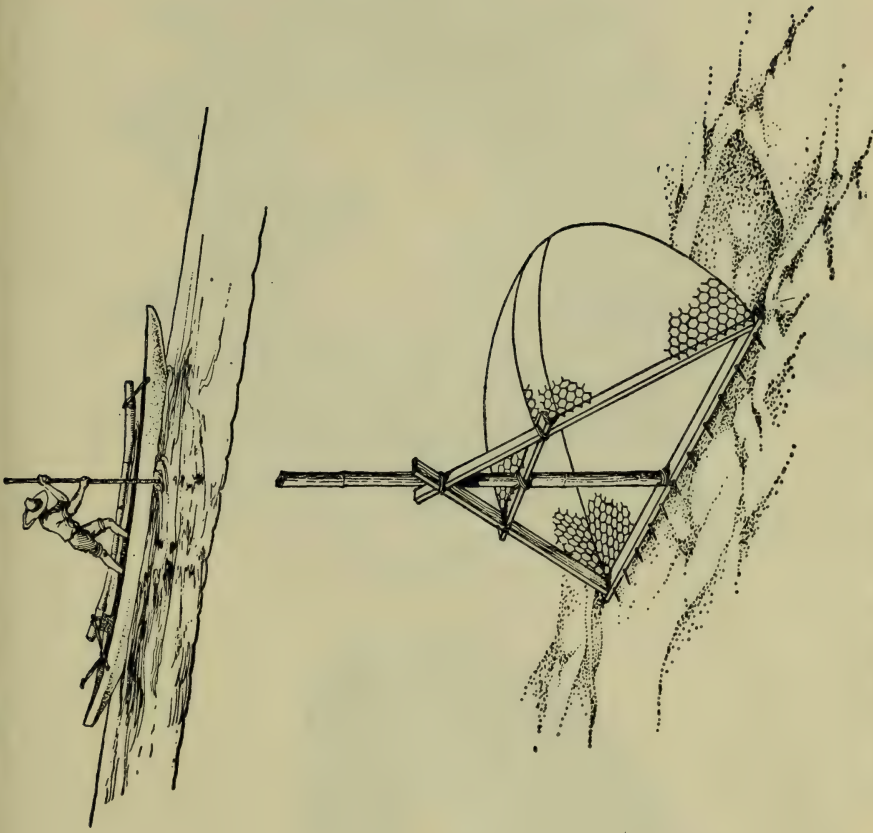

Figure 5.—Pangahig (Tagalog), a rake for collecting snails in Laguna de Bay.

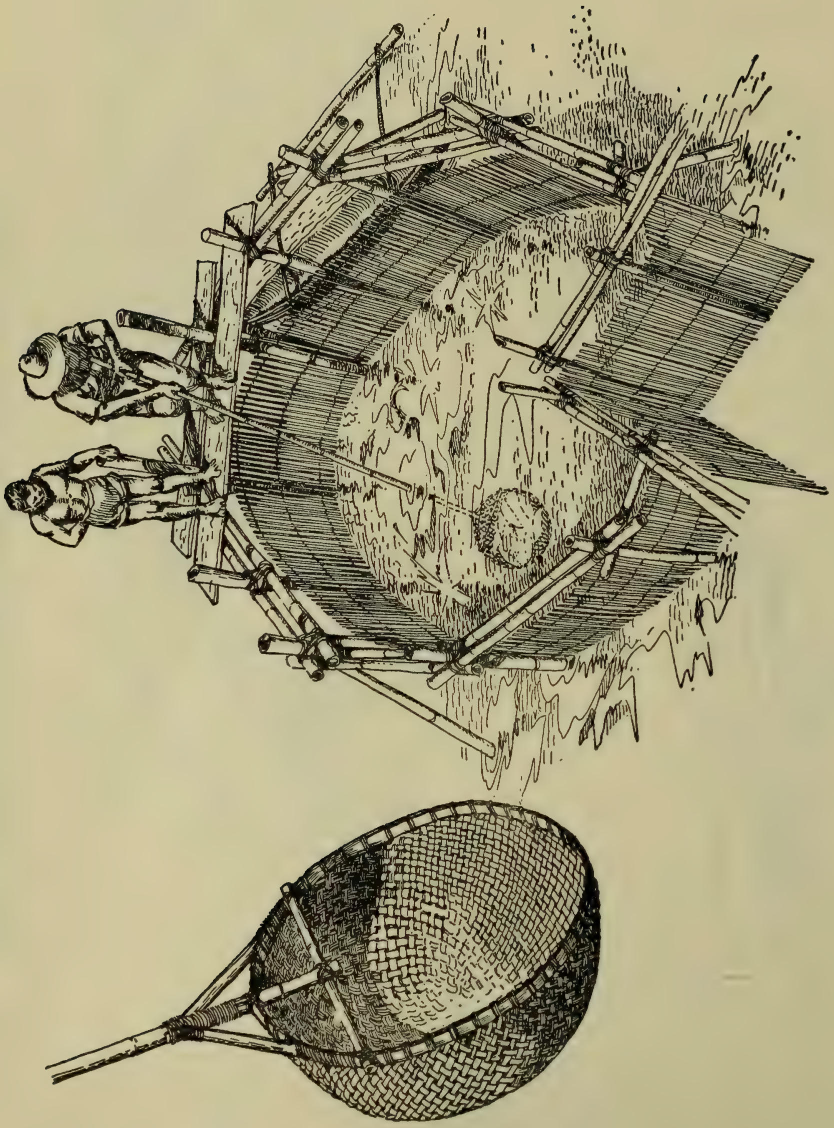

Figure 6.—Panalok (Tagalog), a scoop for brailing out the catch from the collecting pound of fish corrals.

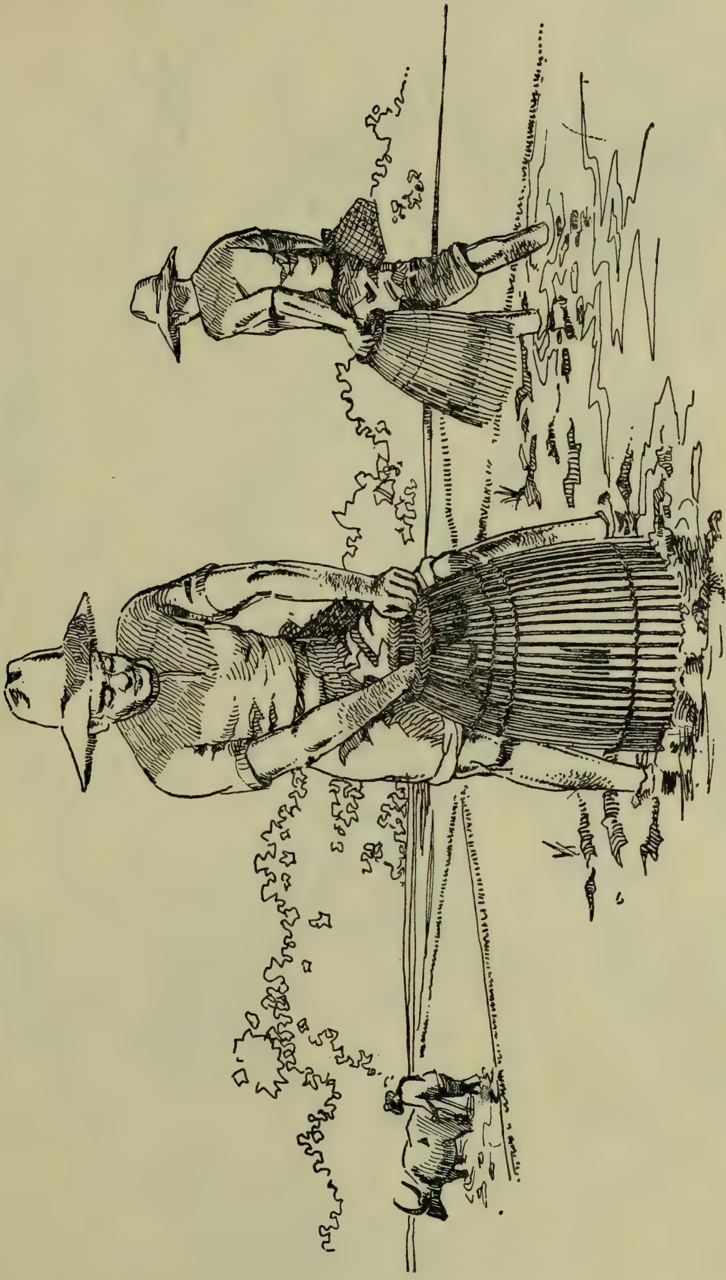

Figure 7.—Salakab (Tagalog), a cover pot for catching dalag in paddy fields and inland bodies of fresh water.

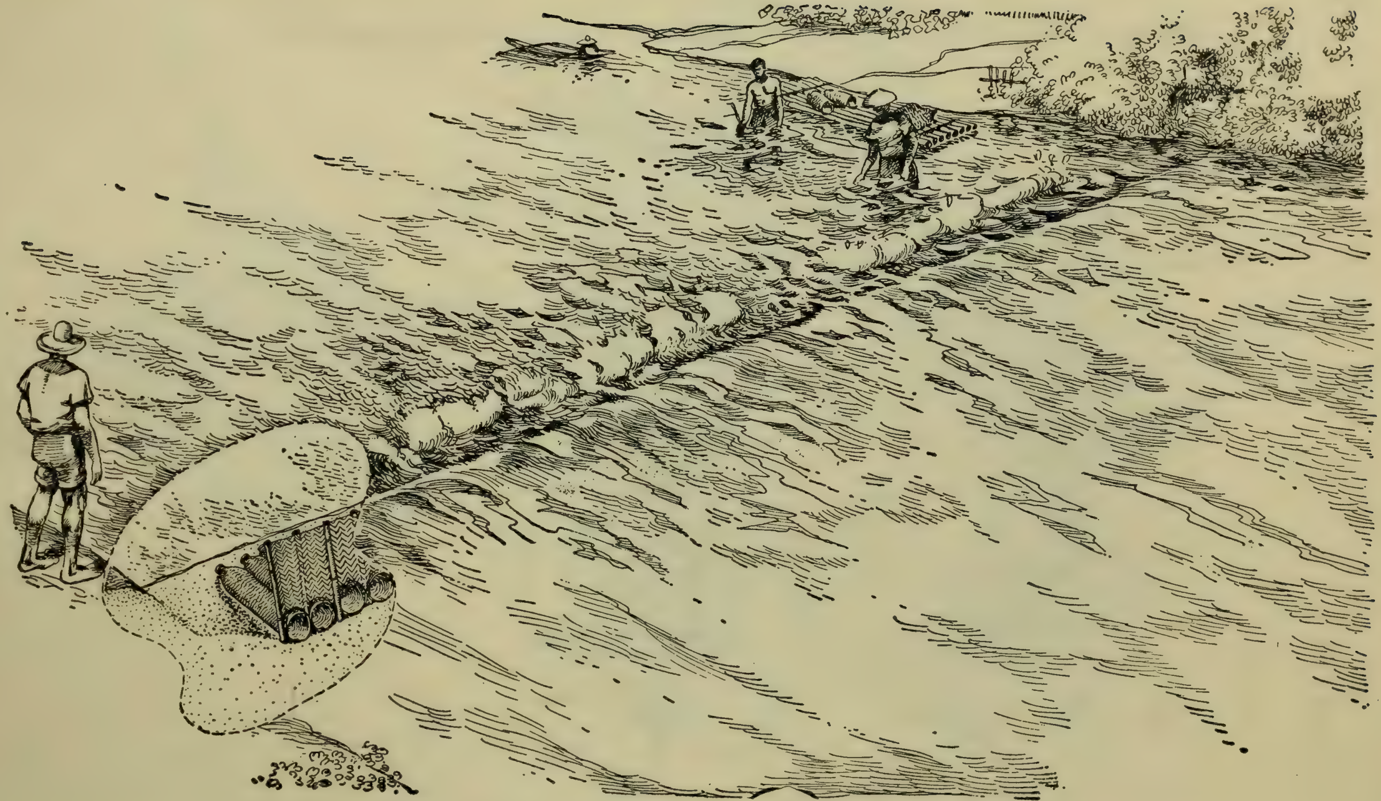

Figure 8.—Pingi (Iloko), a barricade for catching ipon in rivers in northern Luzon.

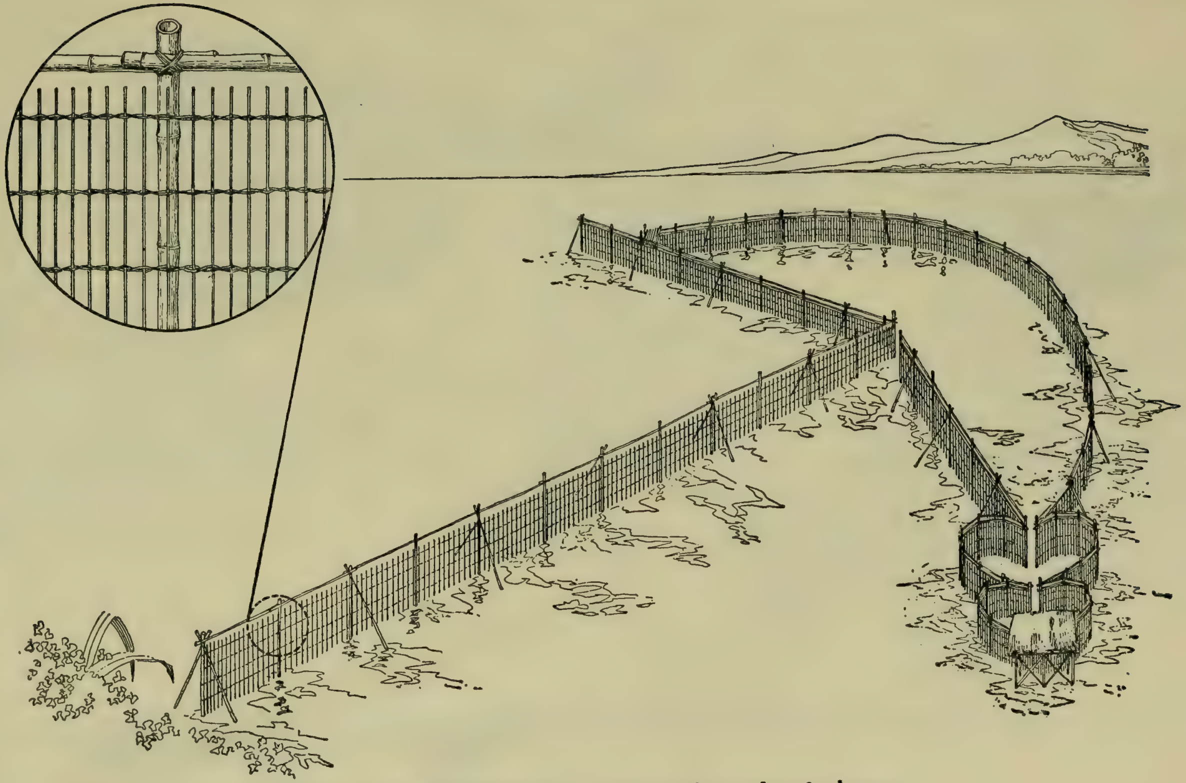

Figure 9.—Baklad (Tagalog), a typical fish corral set in the sea.

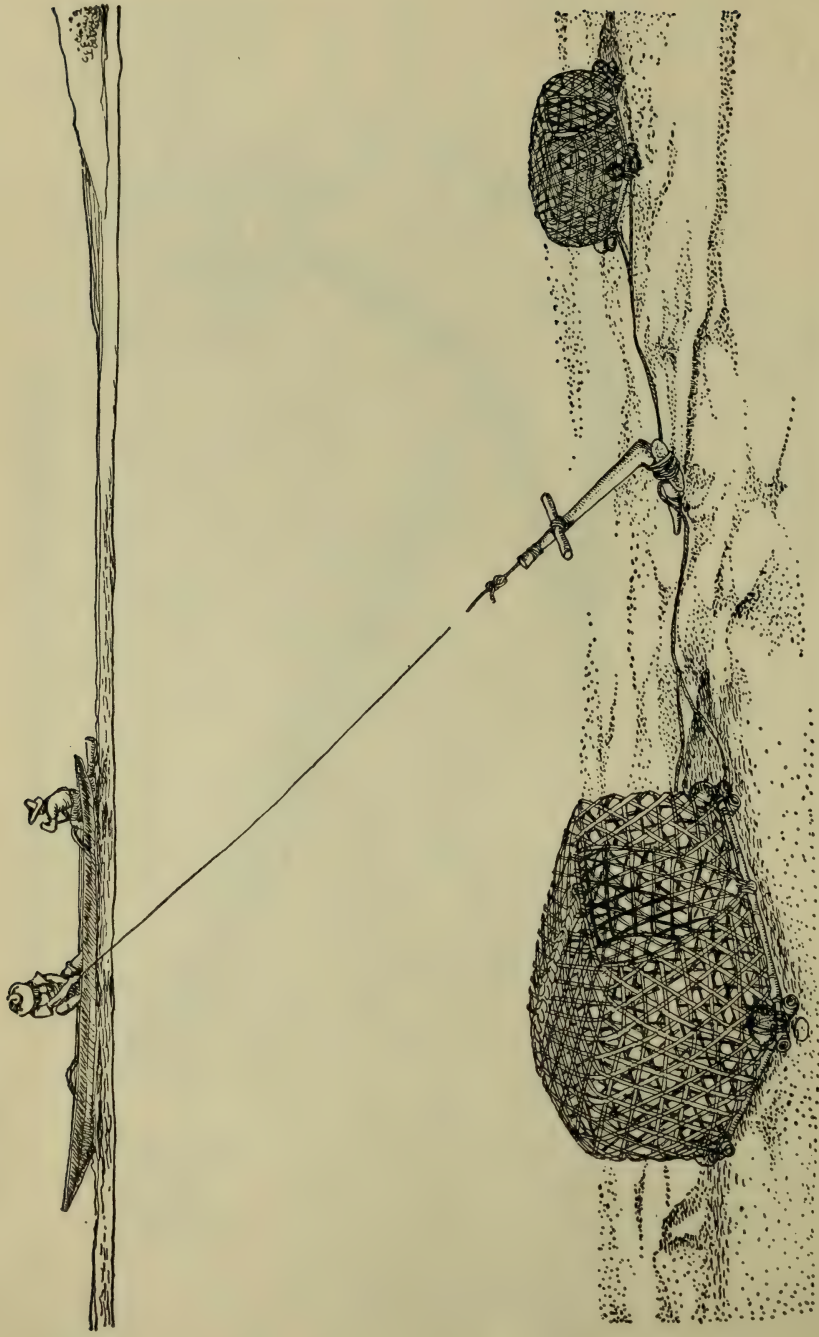

Figure 10.—Bubo (Pilipino), a fish pot for catching coral reef species throughout the Philippines.

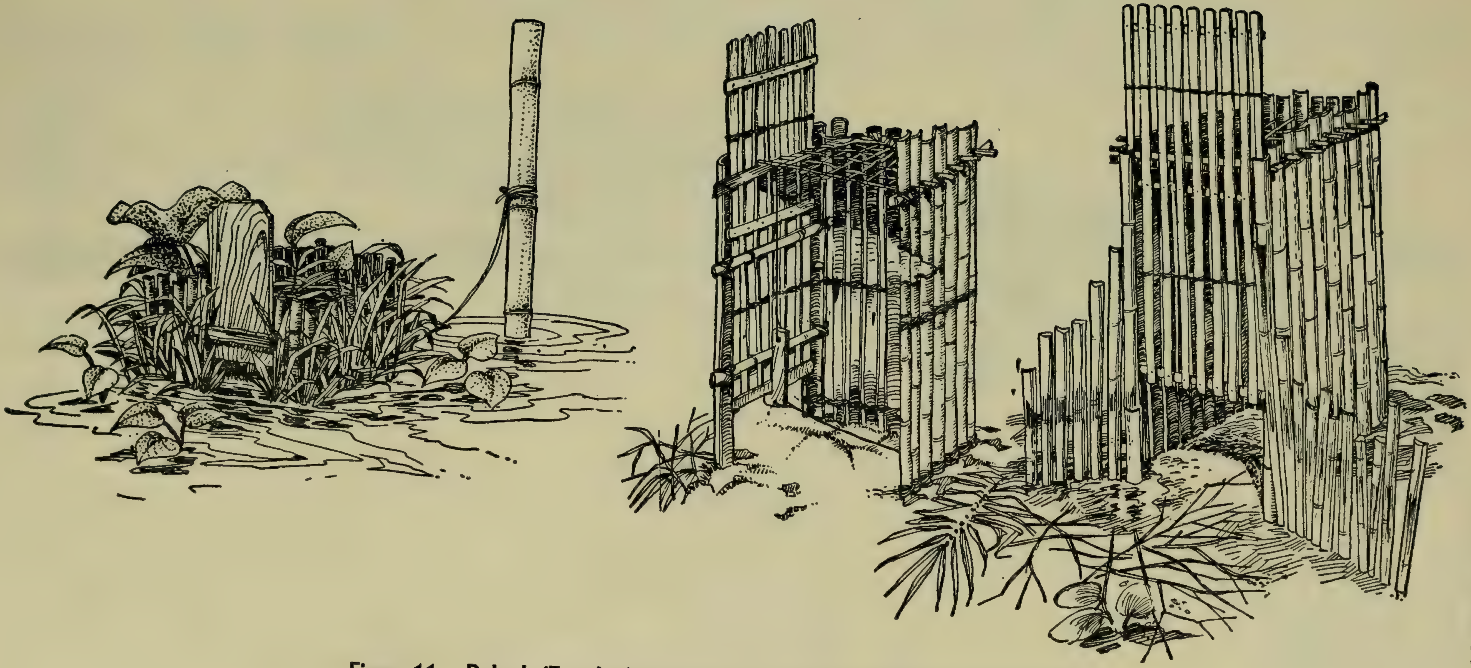

Figure 11.—Paluob (Tagalog), a fish trap for catching dalag in Laguna de Bay.

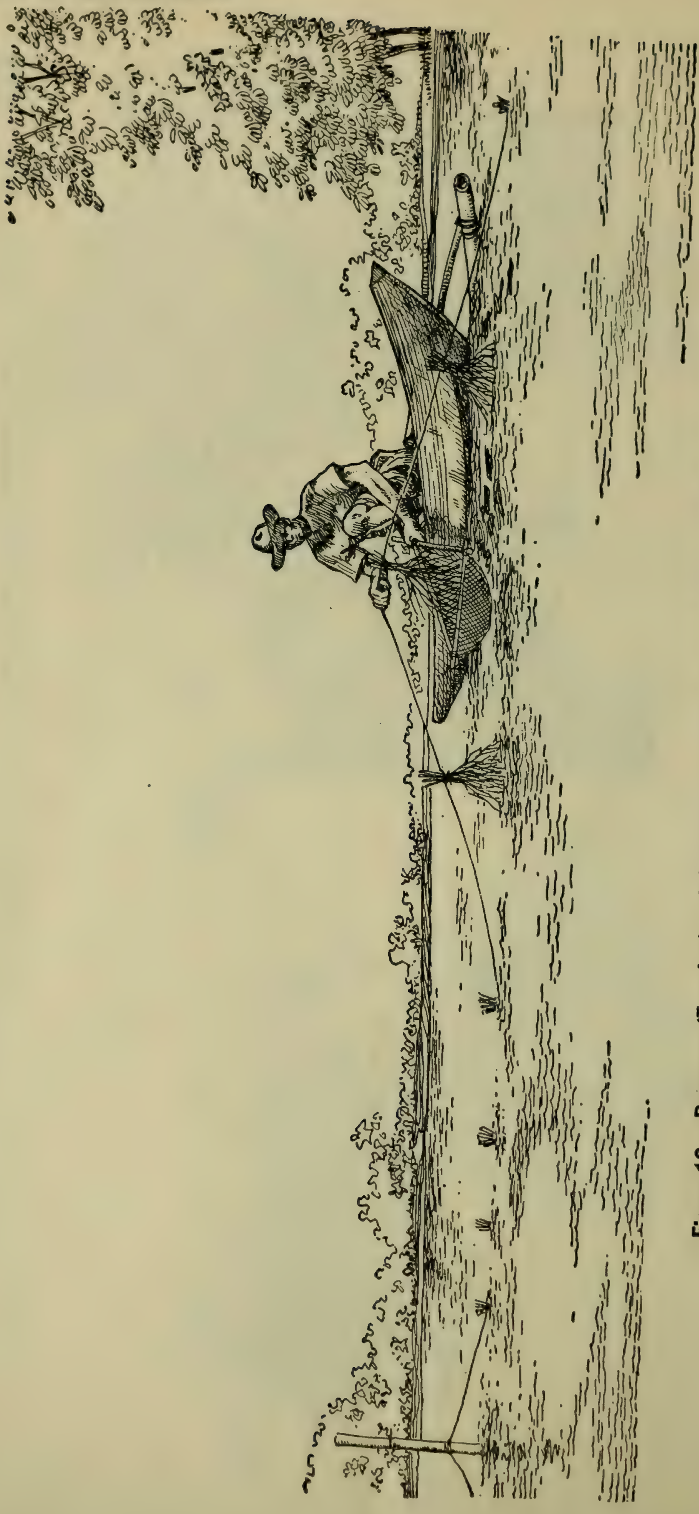

Figure 12.—Panugpo (Tagalog), a fish shelter for catching young shrimps and various other fish fry.

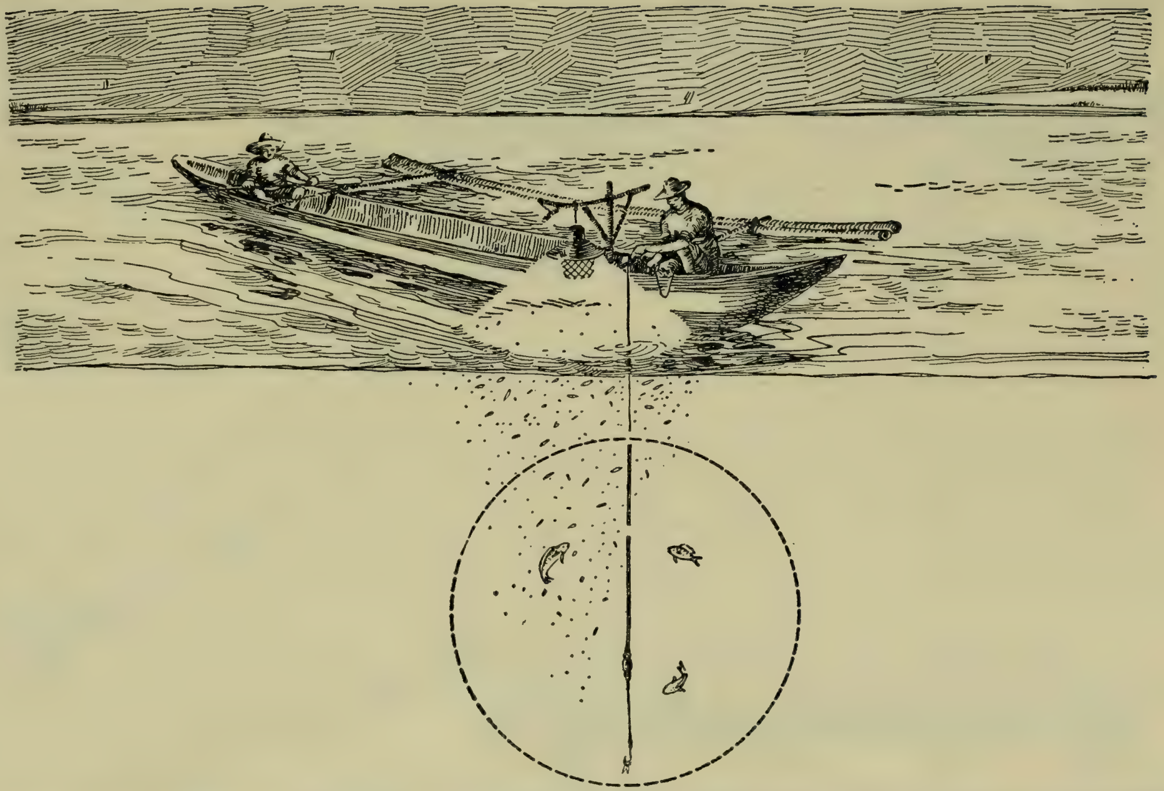

Figure 13.—Kawil (Tagalog), a simple handline for deep-water still fishing usually with the aid of a powerful incandescent lamp.

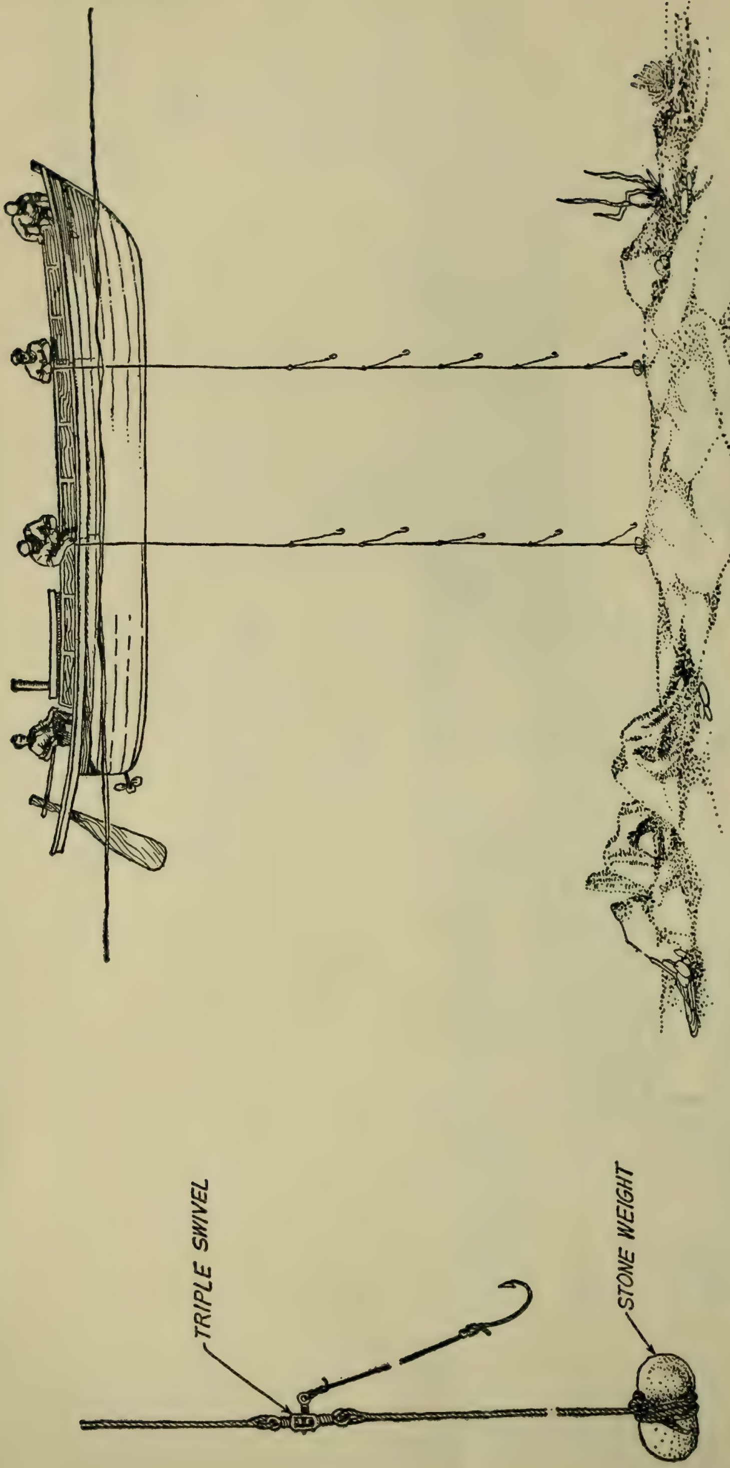

Figure 14.—Kawil-moderno (Tagalog-Spanish), a multiple handline for catching coral reef species.

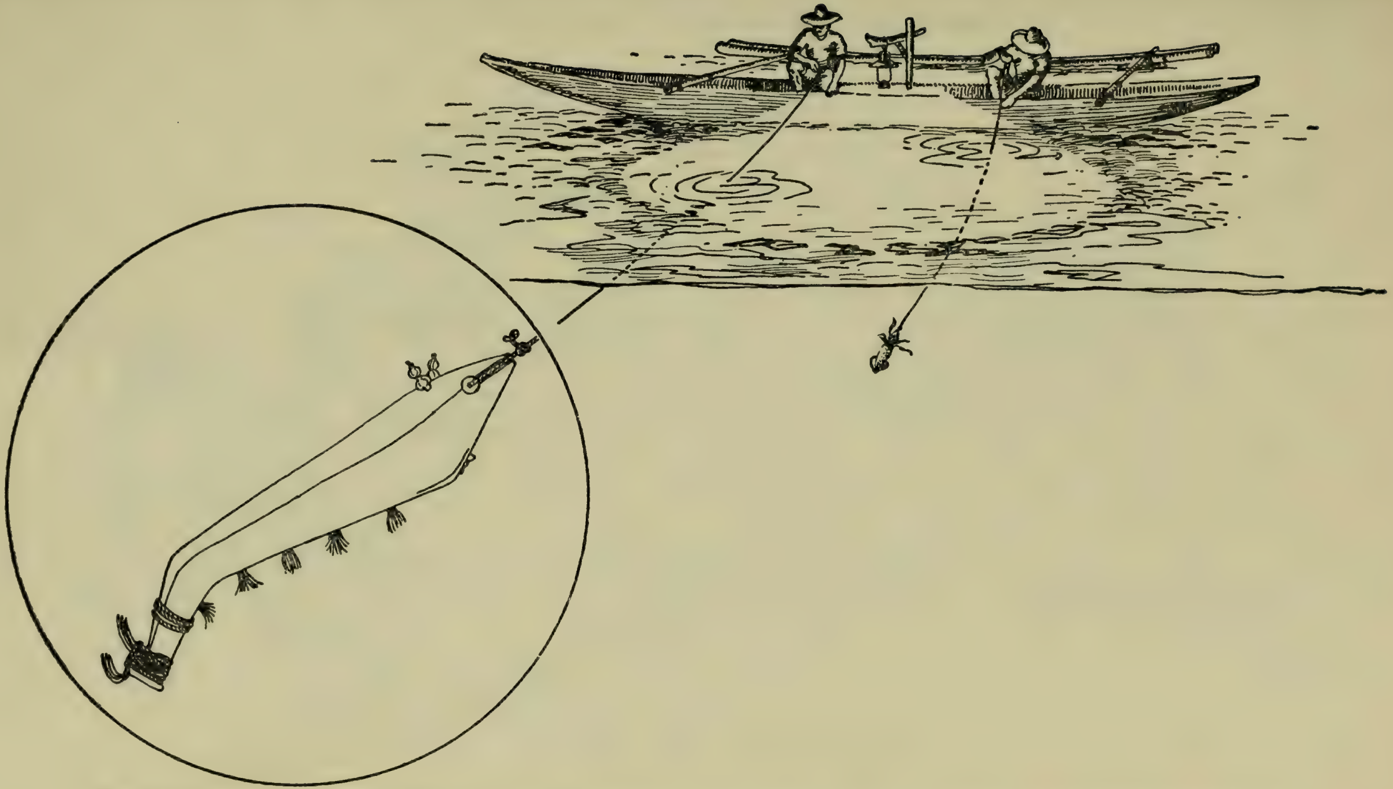

Figure 15.—Lukon-lukon (Ilongo Bisaya), a squid jig commonly employed in the Visayas and Mindanao for catching squids usually with the aid of light.

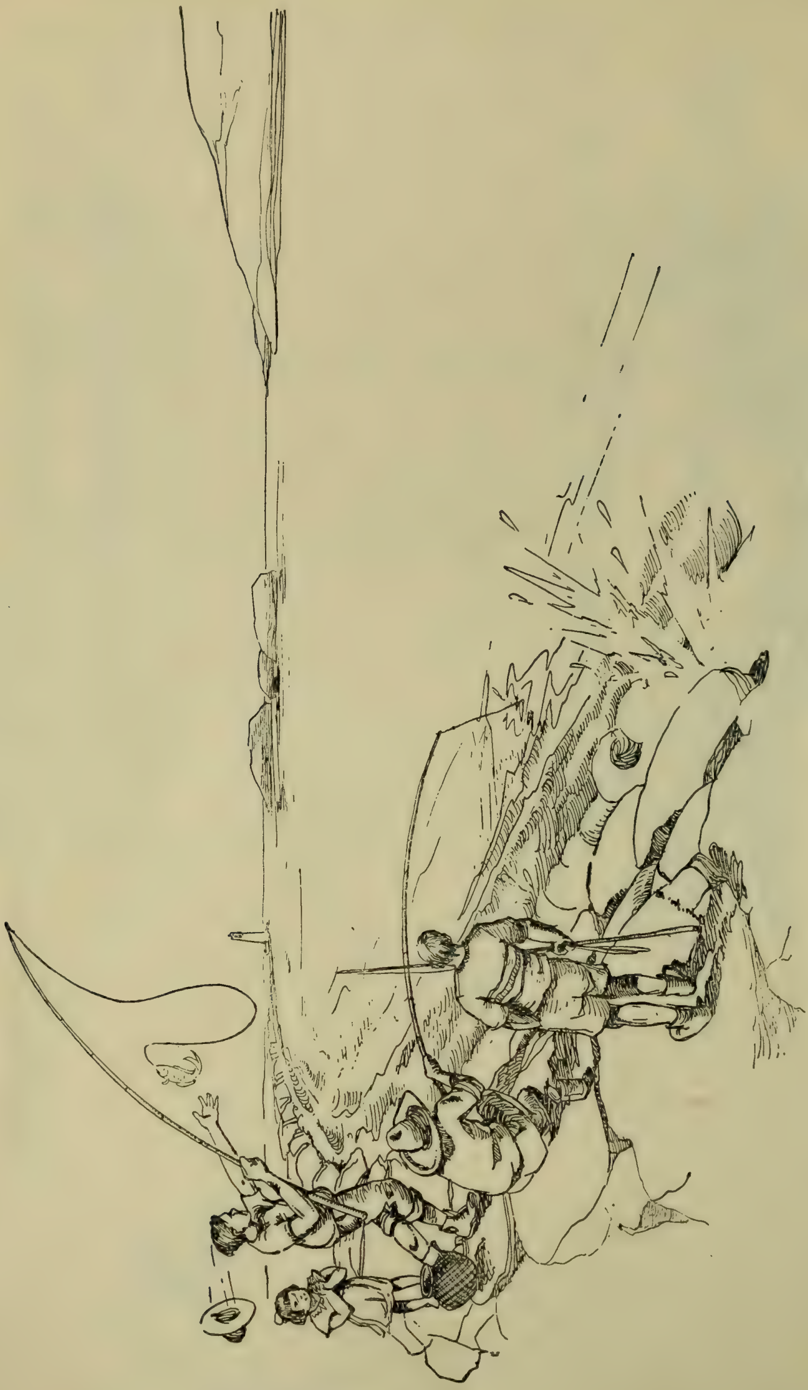

Figure 16.—Biwas or binwit (Tagalog), a pole and line.

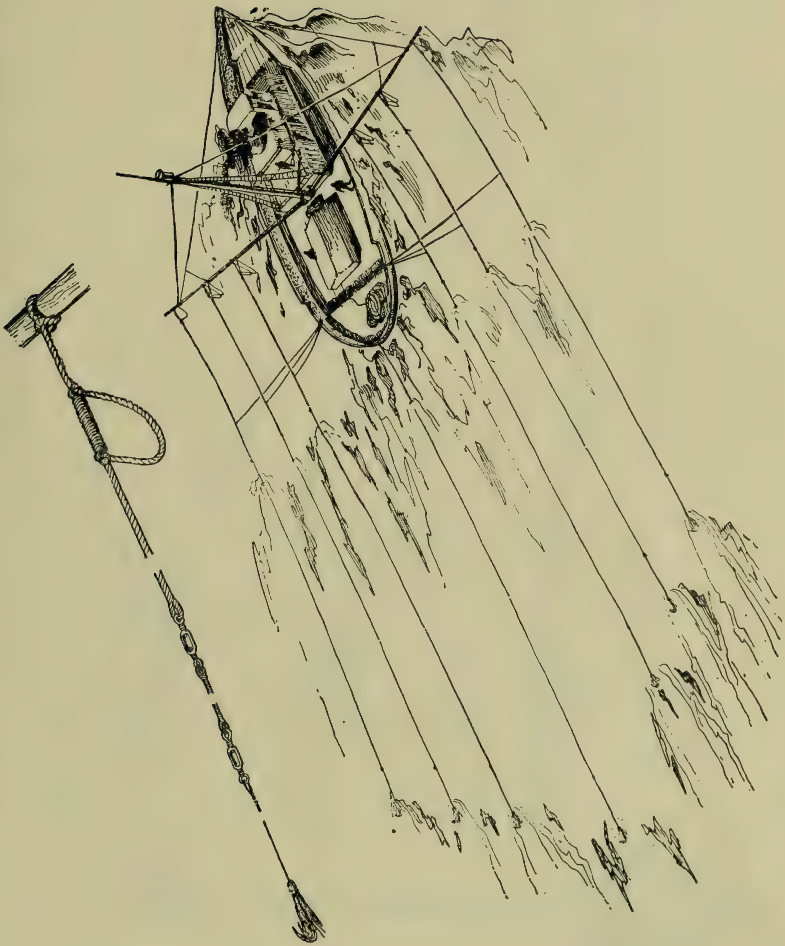

Figure 17.—Sibid-sibid (Tagalog, Bisaya, and Bikol), troll lines used in catching pelagic species.

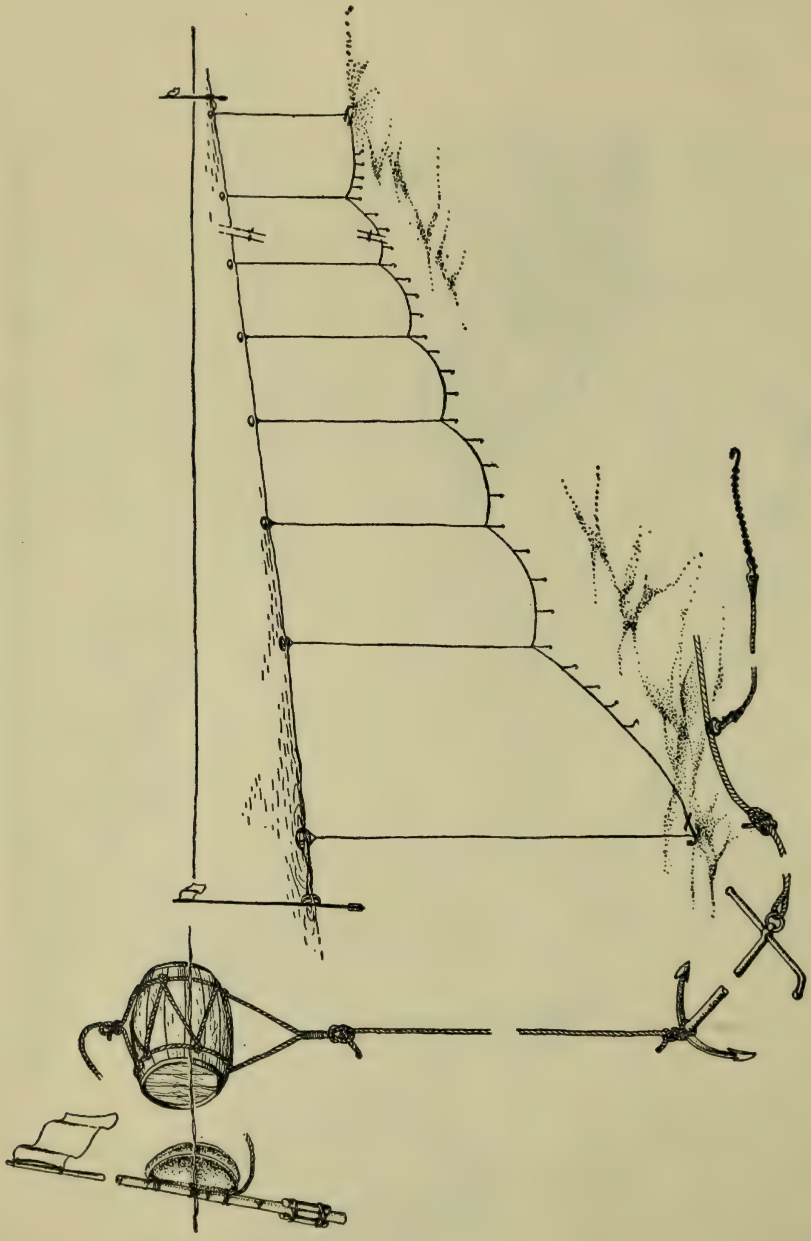

Figure 18.—Set longline for catching sharks.

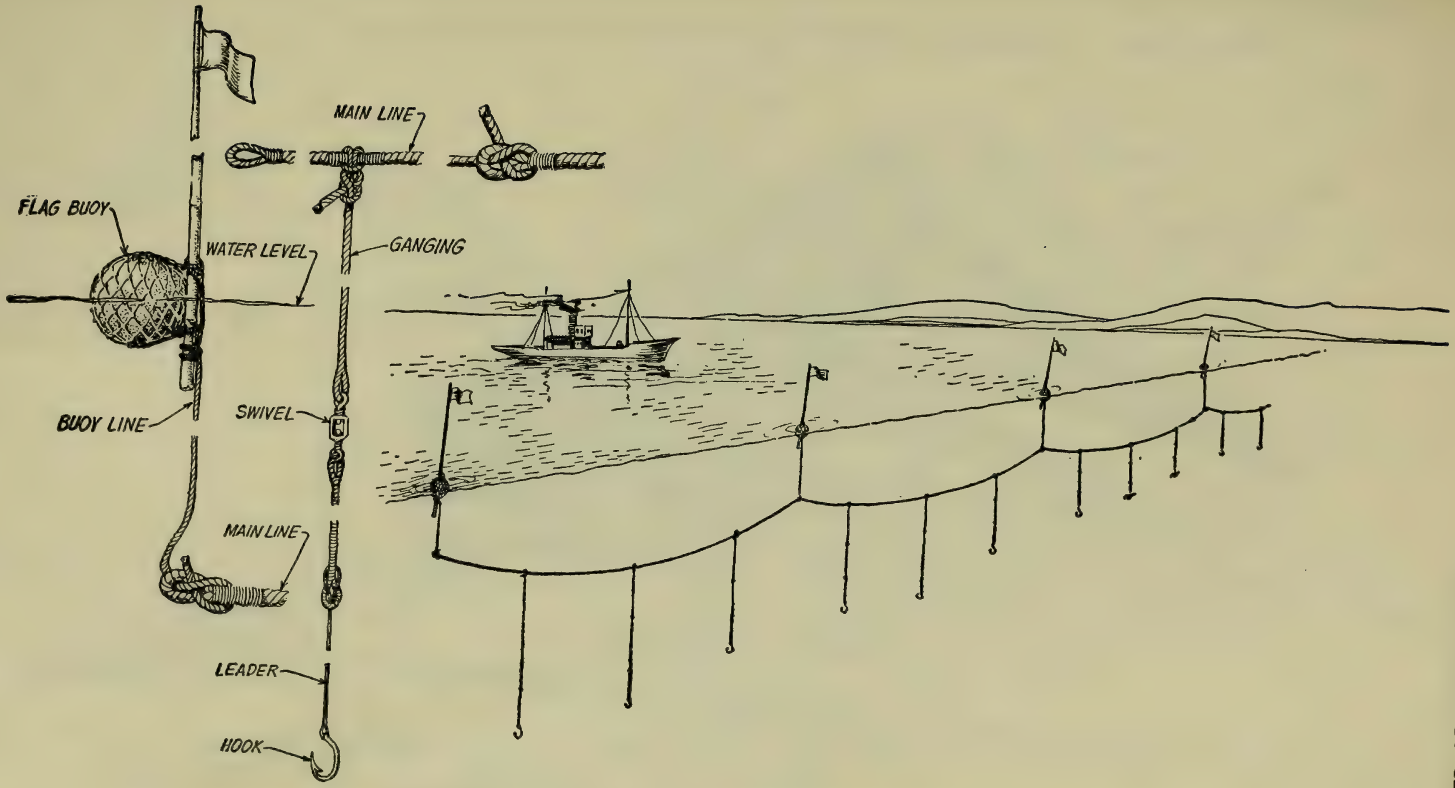

Figure 19.—Drift longline for catching tuna, especially yellowfins.

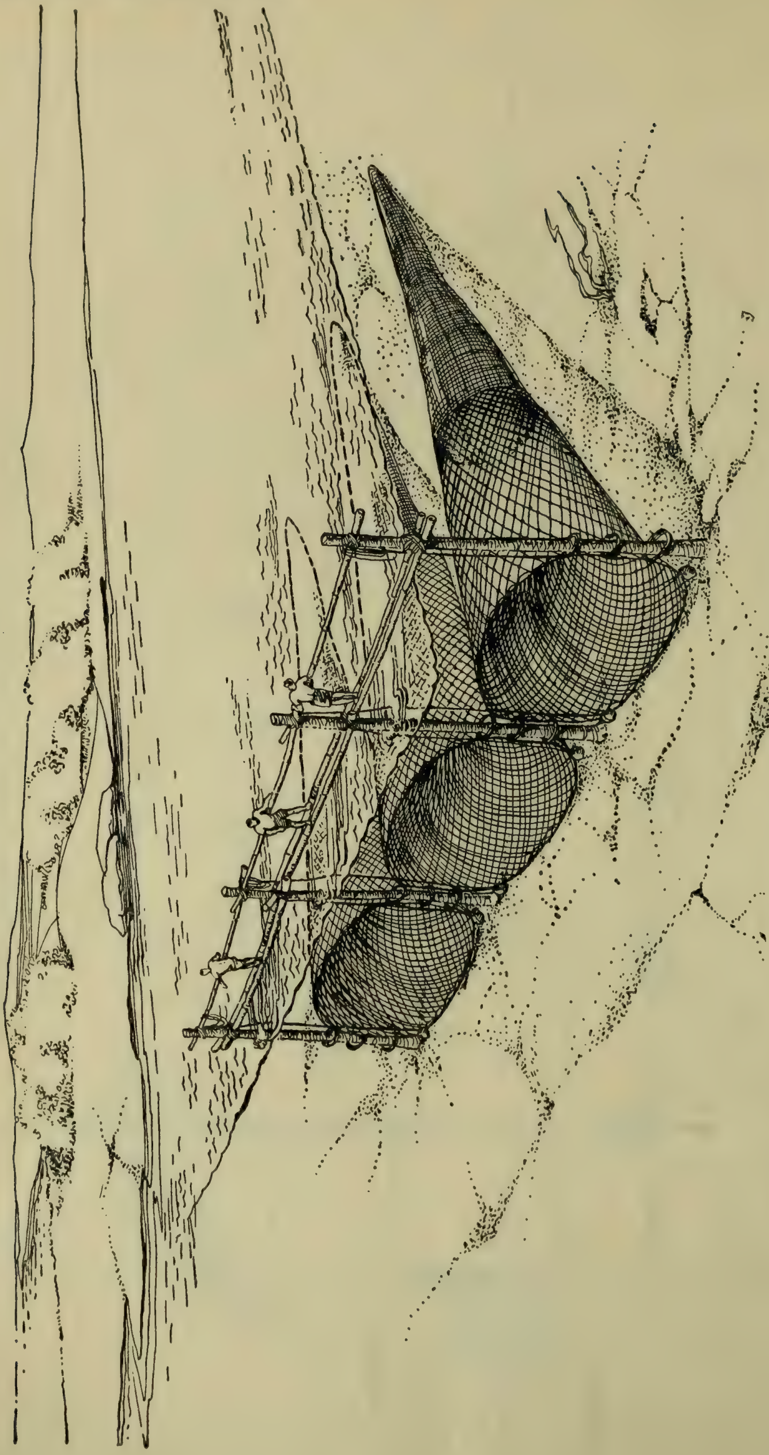

Figure 20.—Tangab (Ilongo Bisaya), filter net in Guimaras Island, Iloilo Province, for catching shrimps.

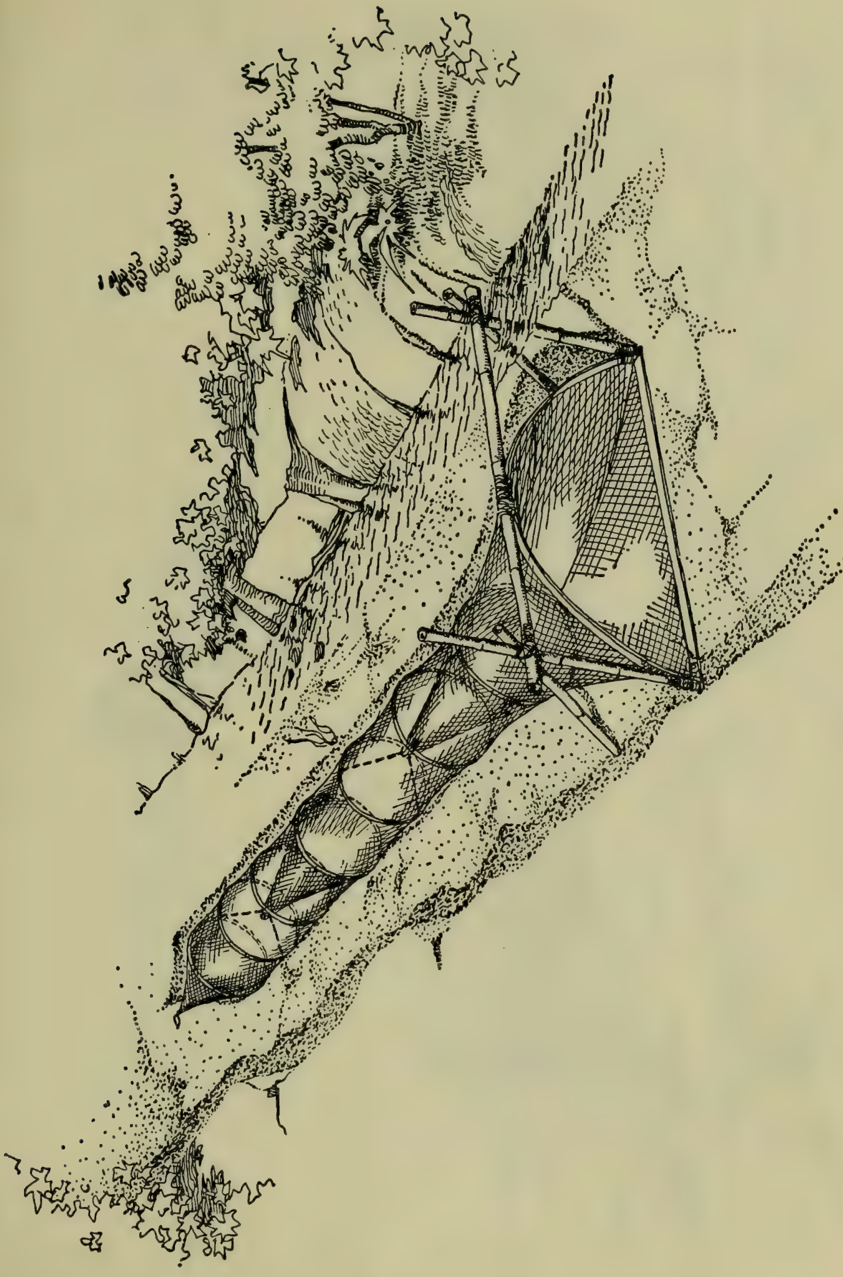

Figure 21.—A hoop net.

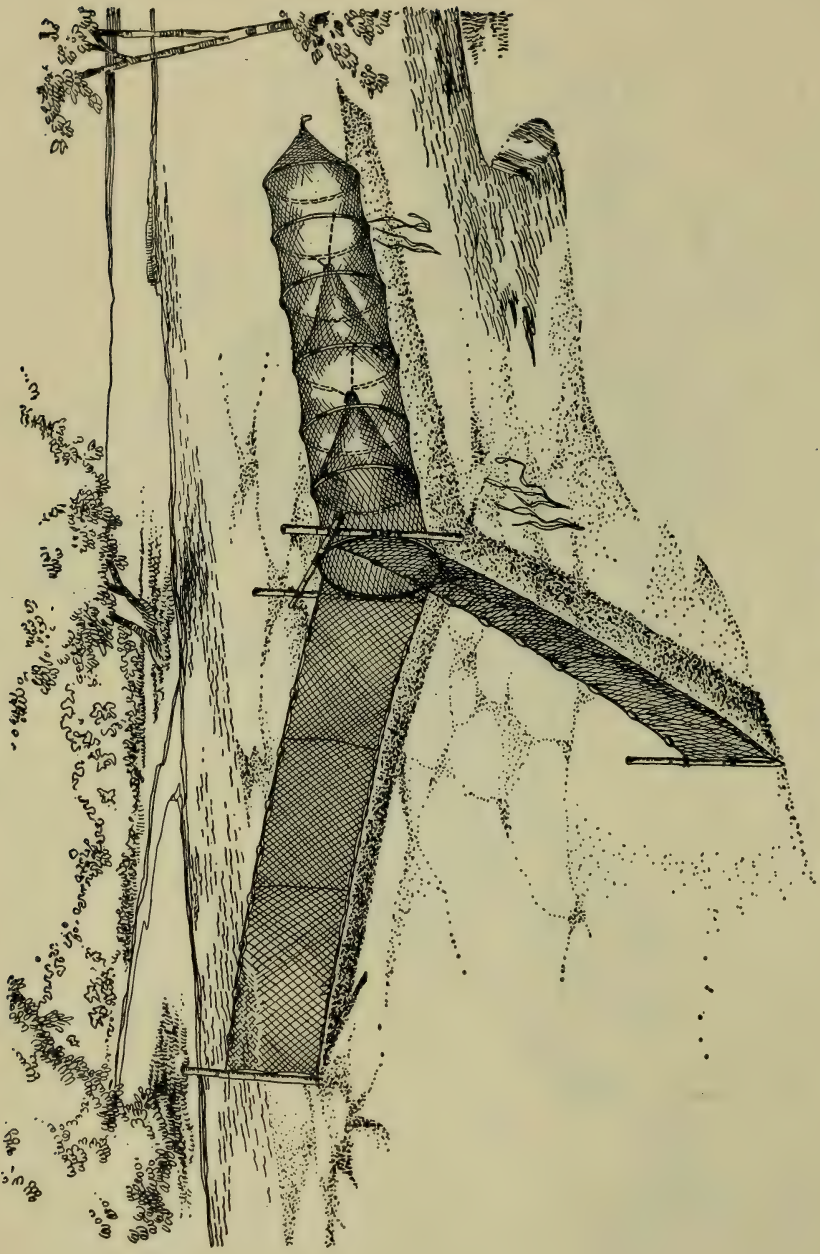

Figure 22.—A fyke net.

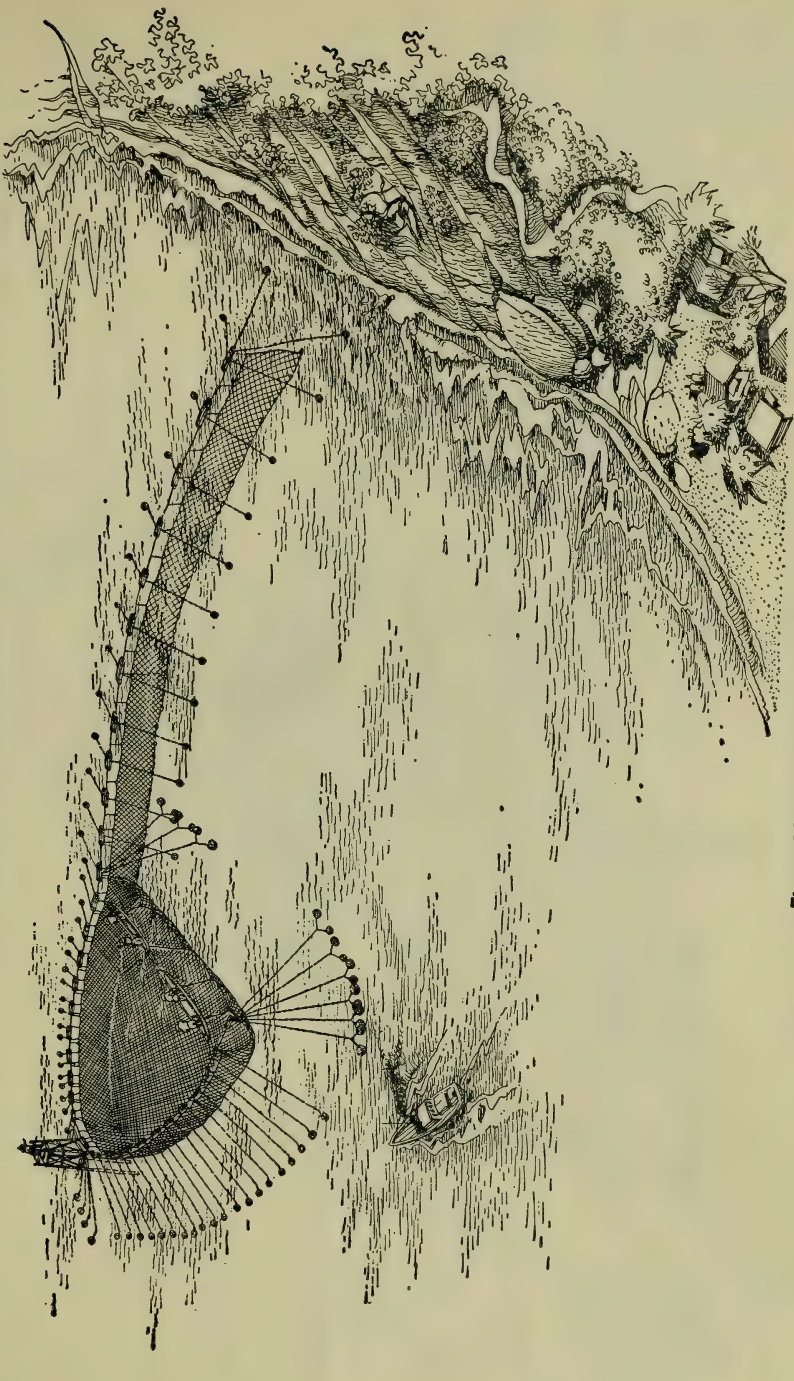

Figure 23.—A trap net for catching bonitos.

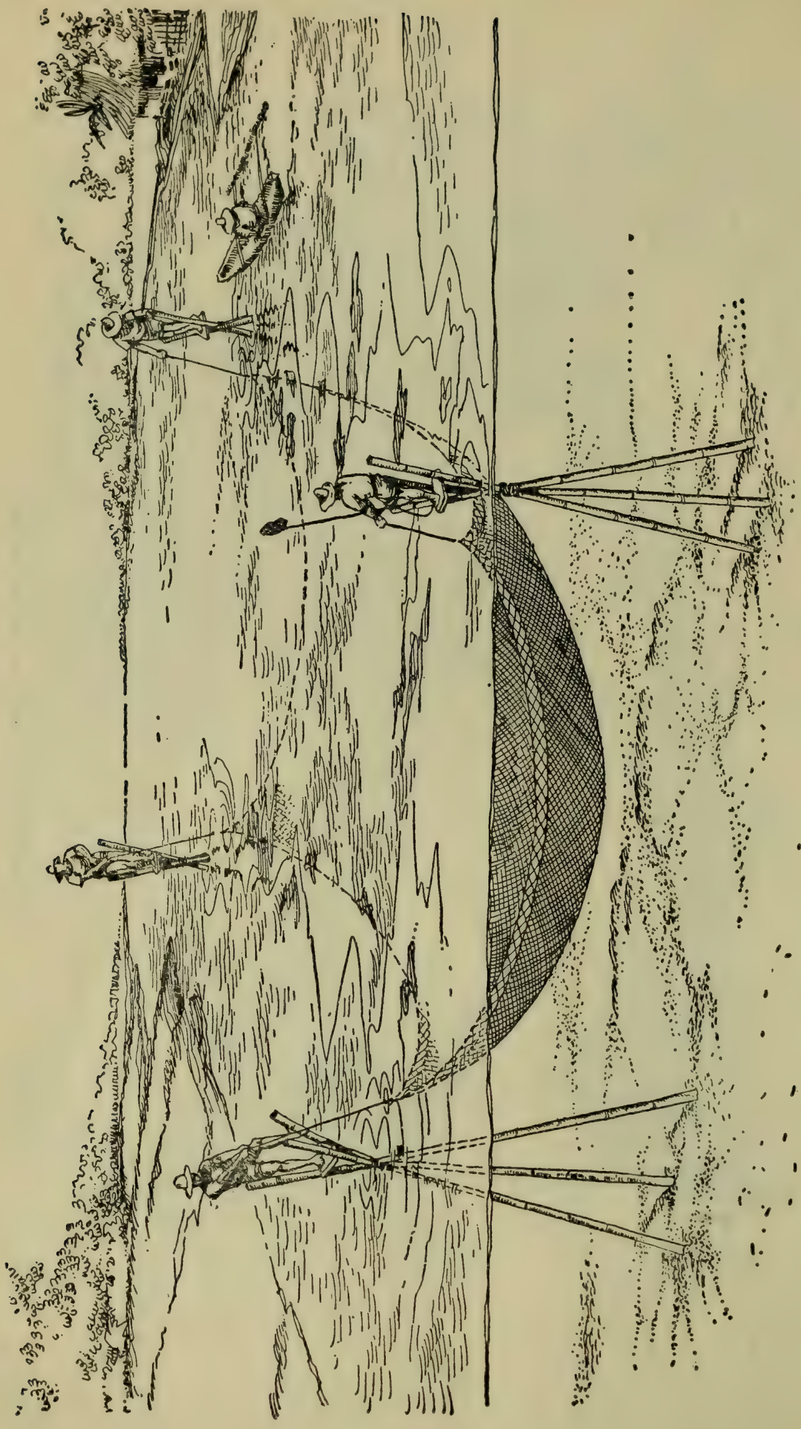

Figure 24.—Kabyaw (Samar-Bisaya), a typical example of a lift net used in rivers for catching mullets.

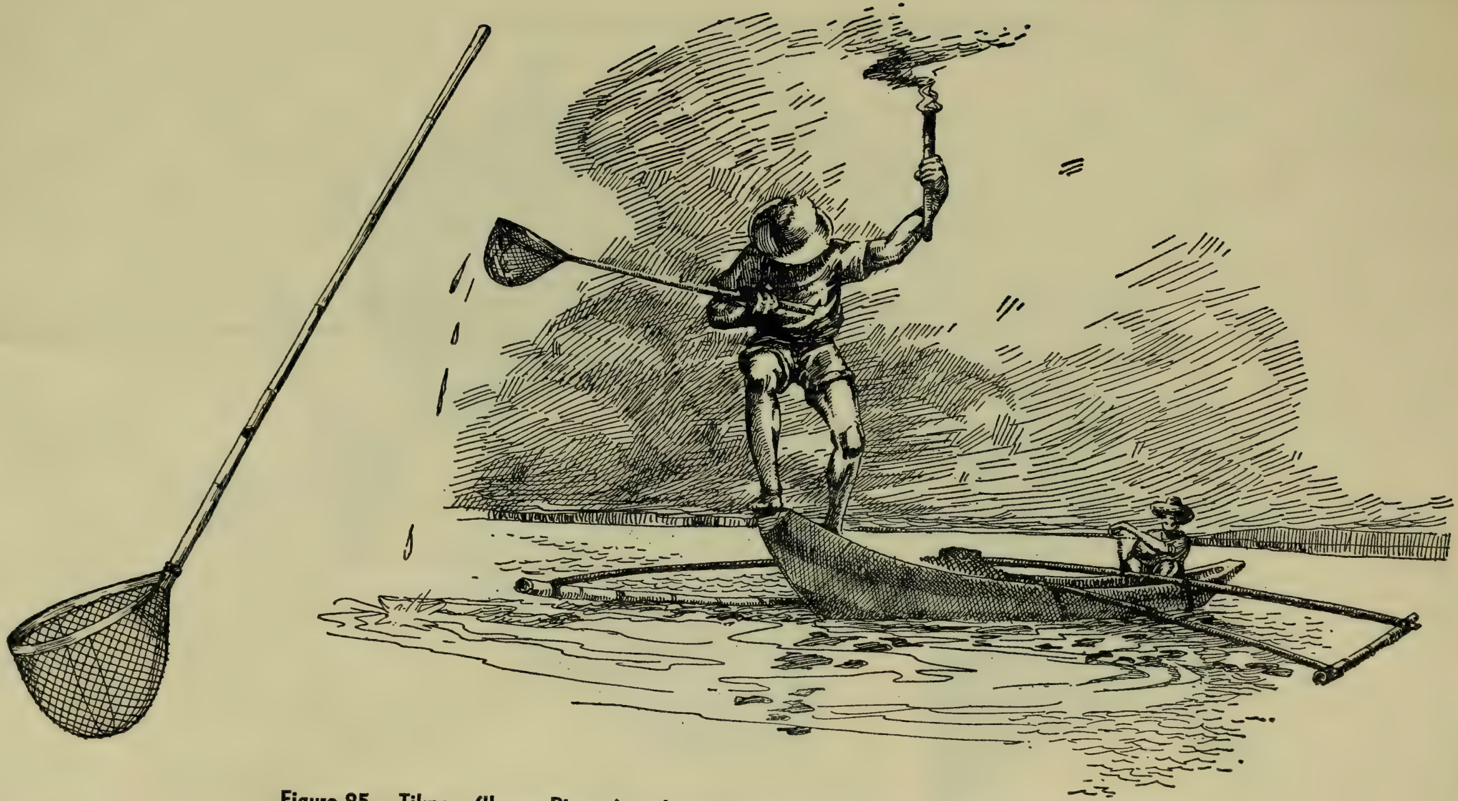

Figure 25.—Tikpaw (Ilongo-Bisaya), a dip net employed in scooping fish attracted to a light.

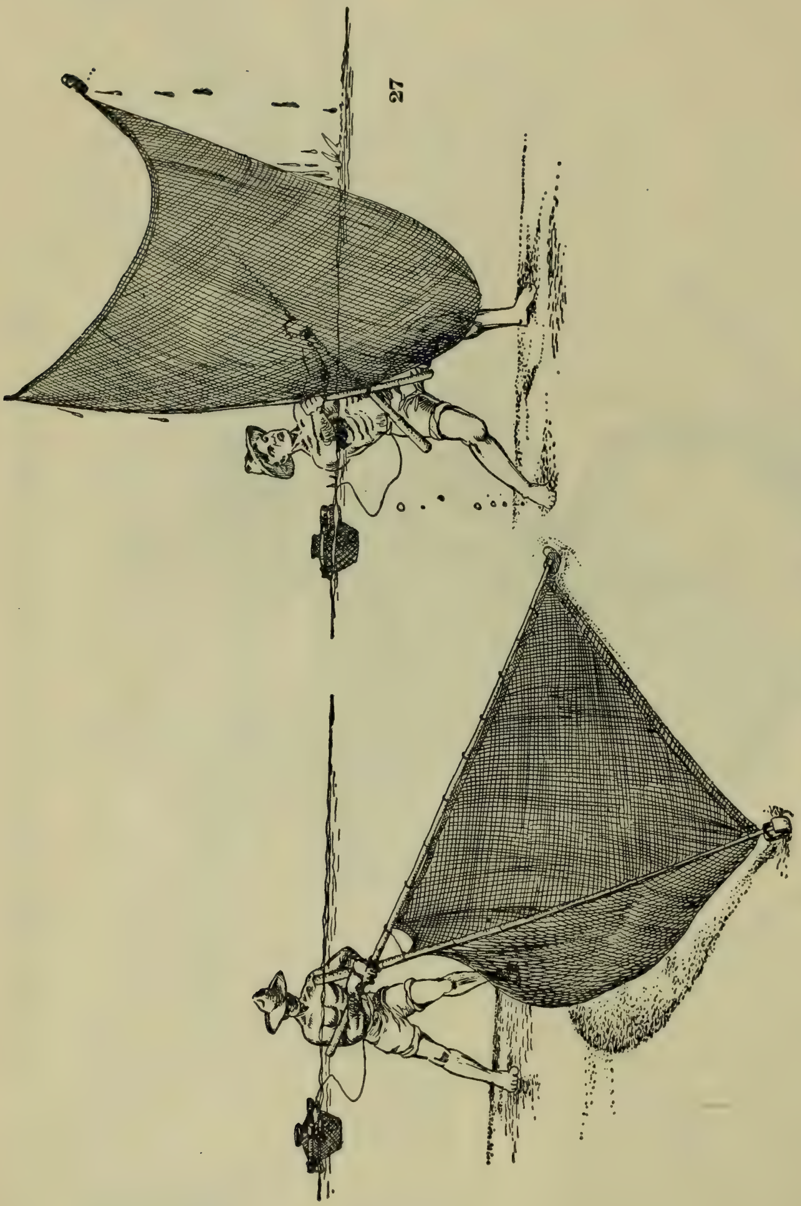

Figure 26.—Sakag (Tagalog), a push net for catching shrimps.

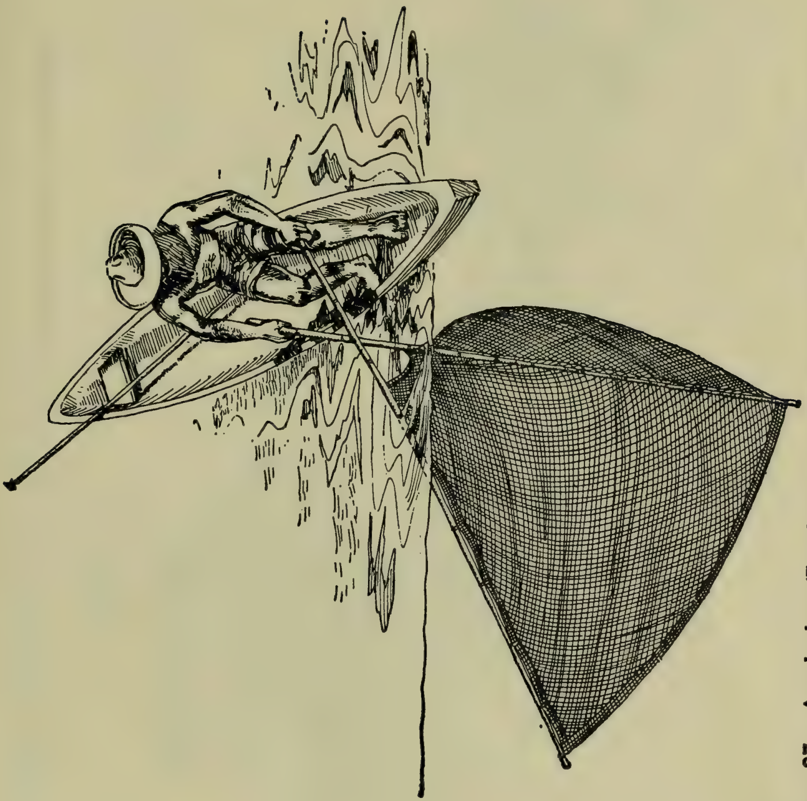

Figure 27.—Anod-sulong (Tagalog), a skimming net for catching shrimps in waters beyond wading depths.

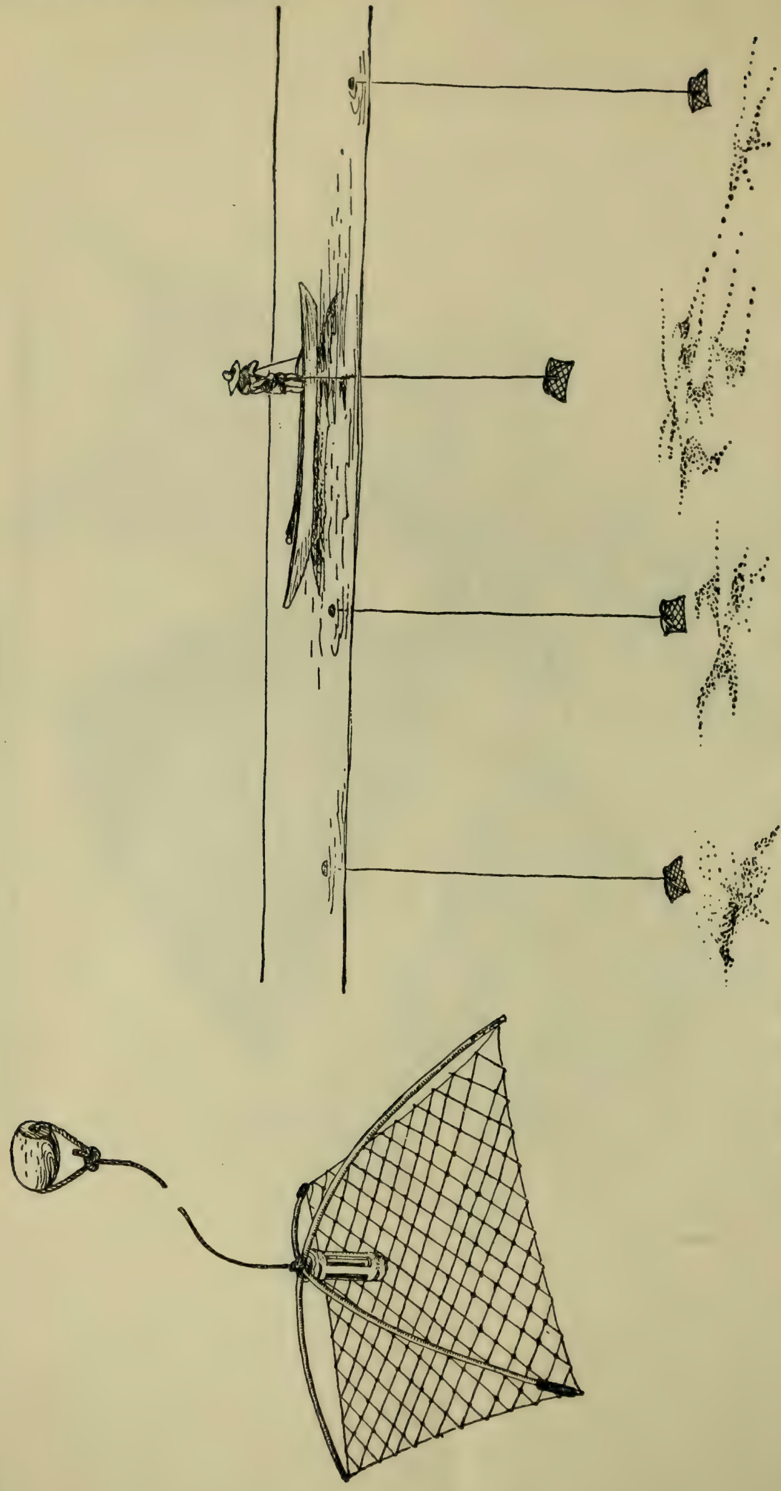

Figure 28.—Bintol (Tagalog), a crab lift net for catching alimasag, a swimming crab.

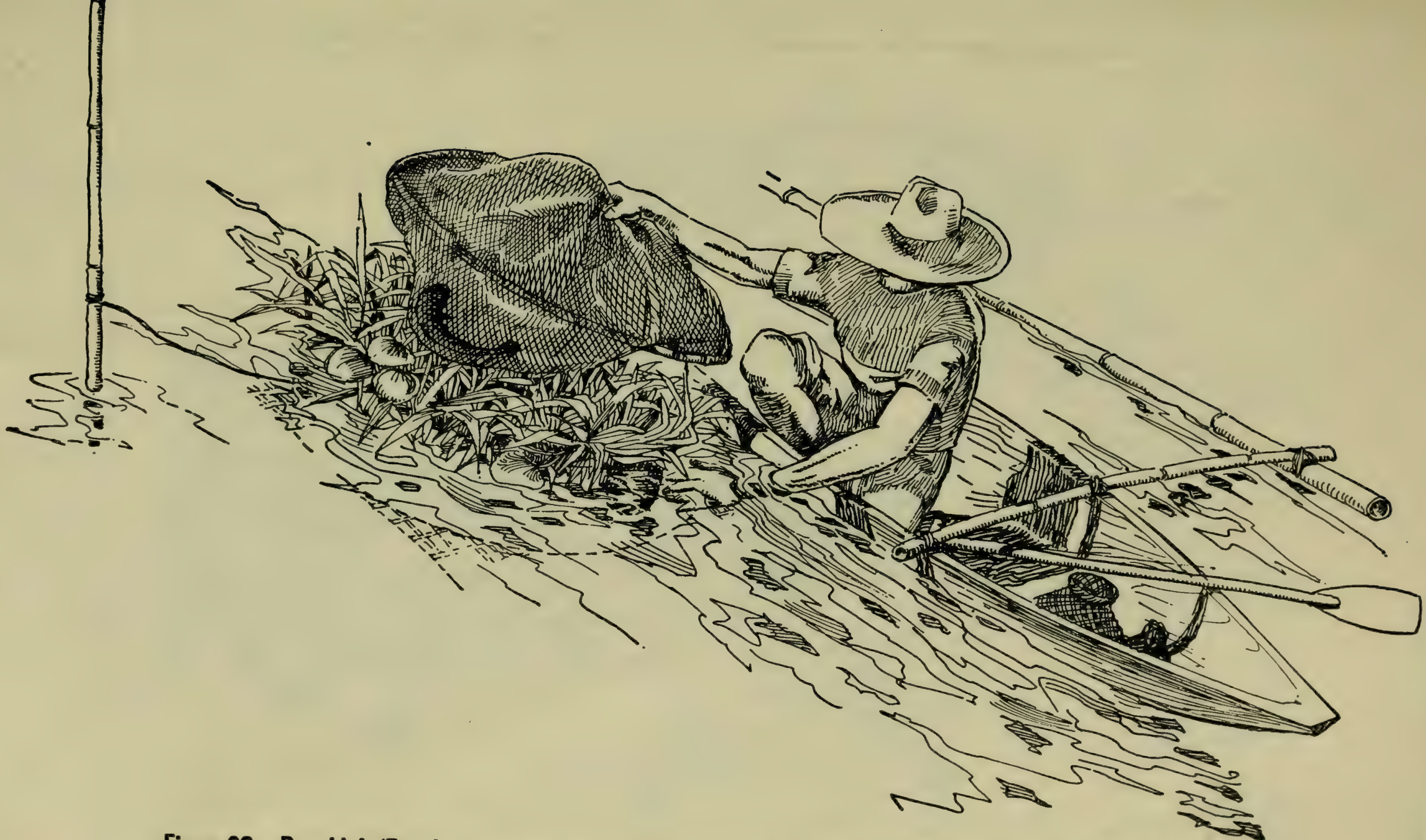

Figure 29.—Panaklob (Tagalog), a cover net for catching dalag in the pugad-pugad (Tag.), the latter a fish shelter.

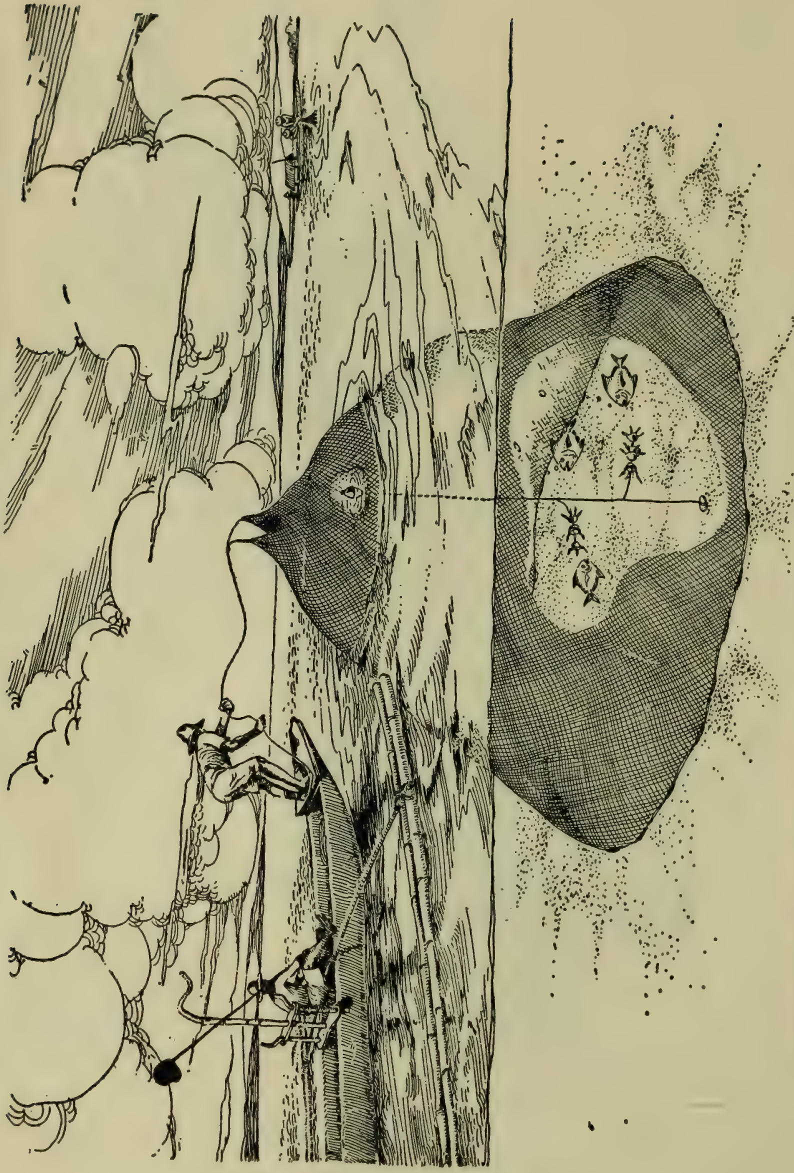

Figure 30.—Pangduhay (Tagalog), a special deep-water cast net for catching duhay, a pomfret.

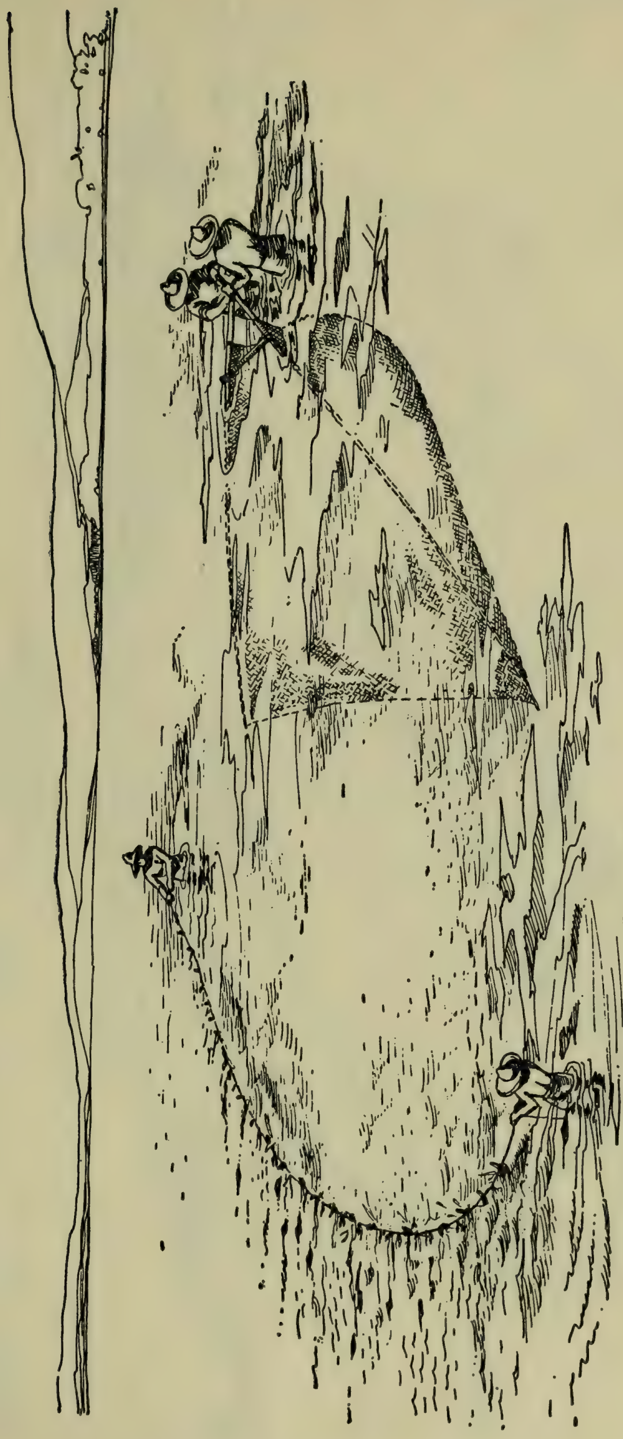

Figure 31.—Surambaw (Bisaya), an example of a drive-in-net.

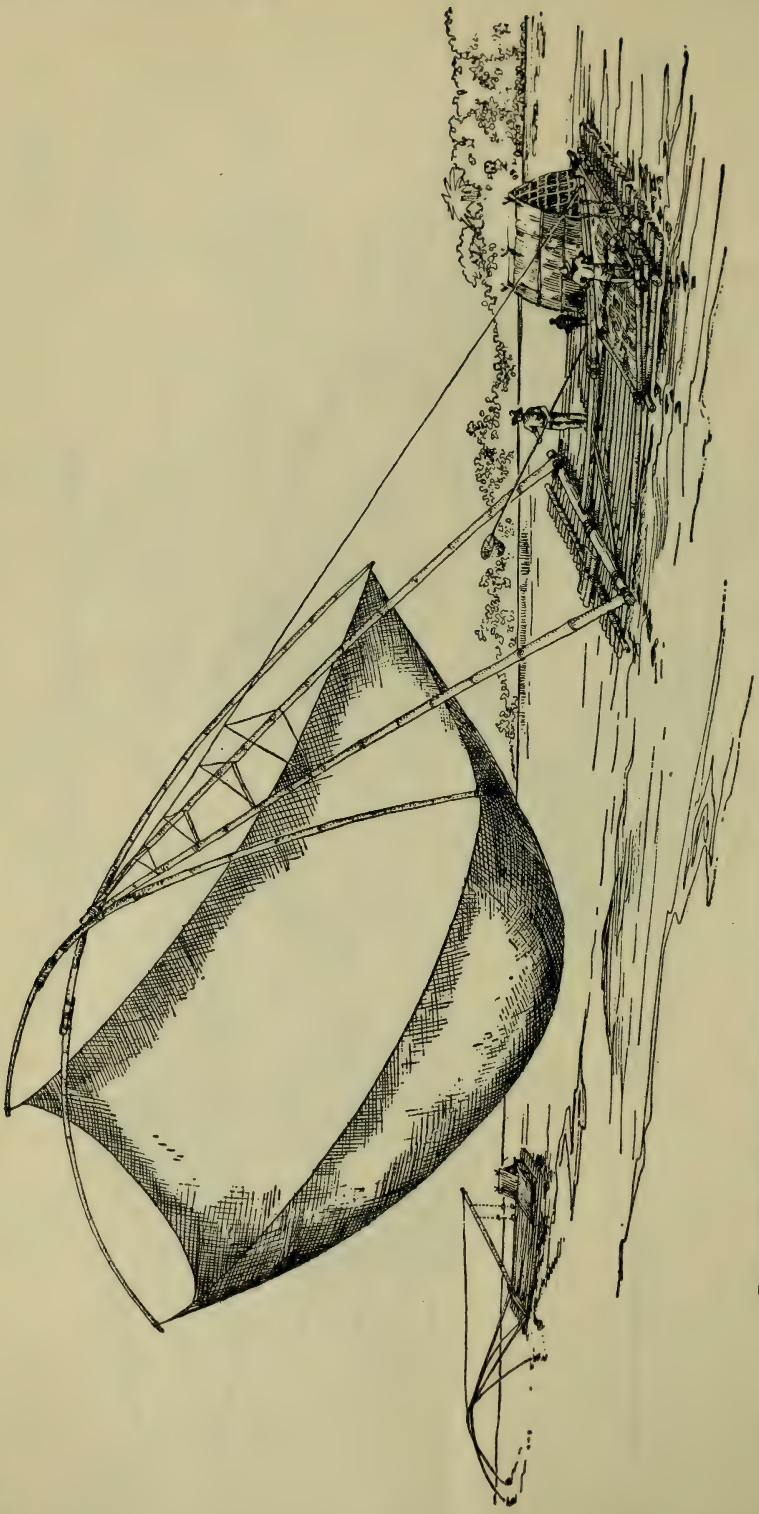

Figure 32.—Salambaw (Tagalog), a lever net for catching small fishes, especially mullets in rivers near Manila.

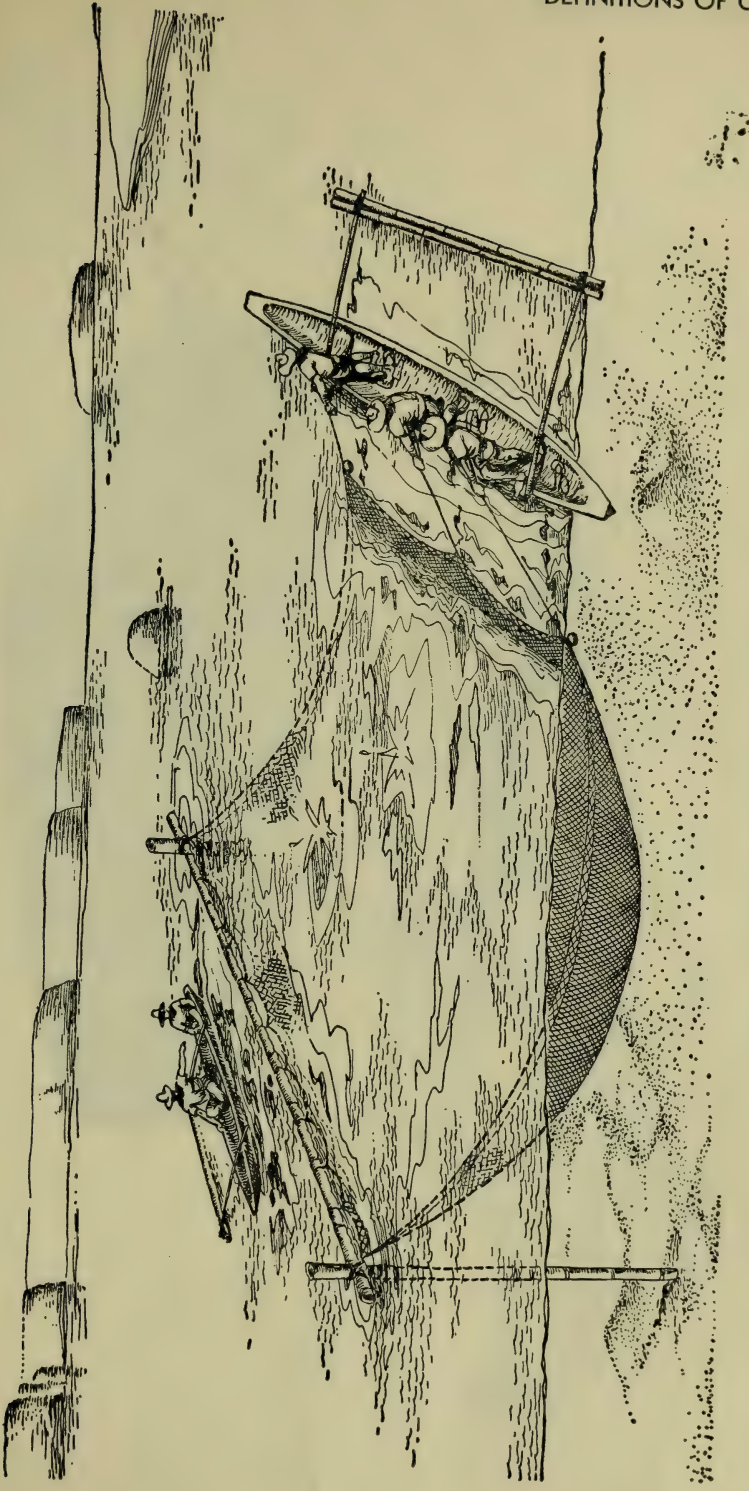

Figure 33.—Kabyaw (Samar-Bisaya), an example of a blanket net.

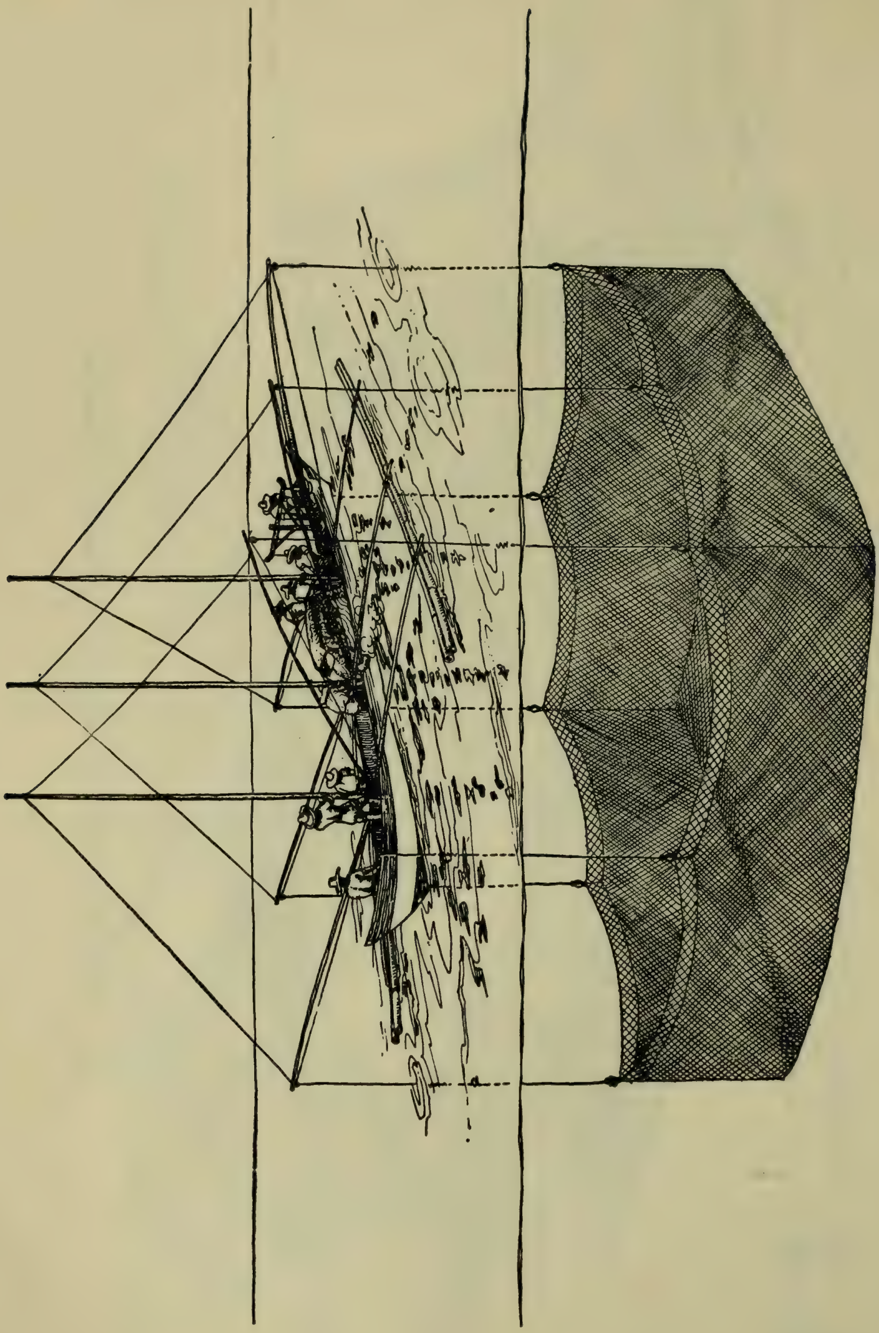

Figure 34.—Basnig (Pilipino), a typical bag net.

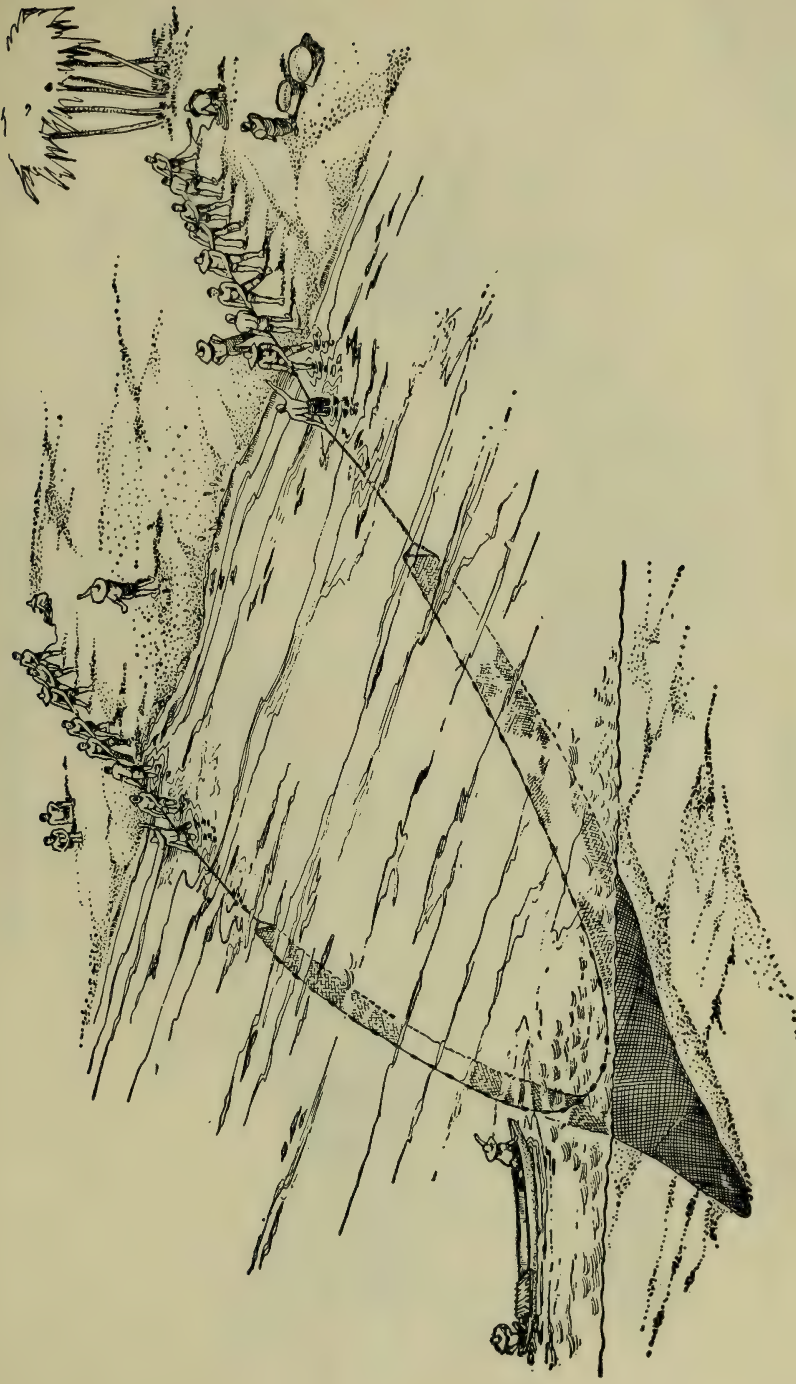

Figure 35.—Pukot (Pilipino), a typical beach seine.

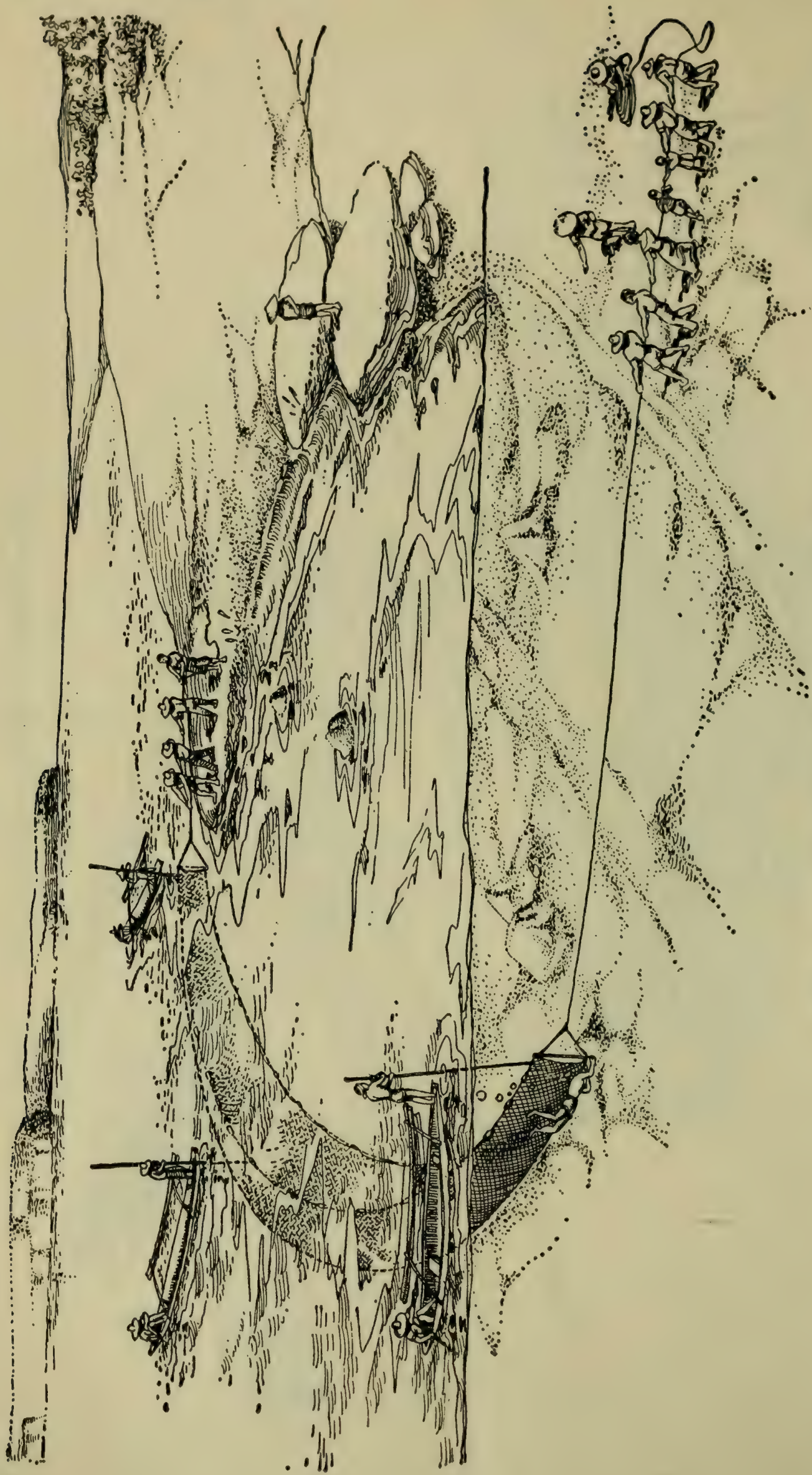

Figure 36.—Ligkop (Samar-Bisaya), a typical reef seine.

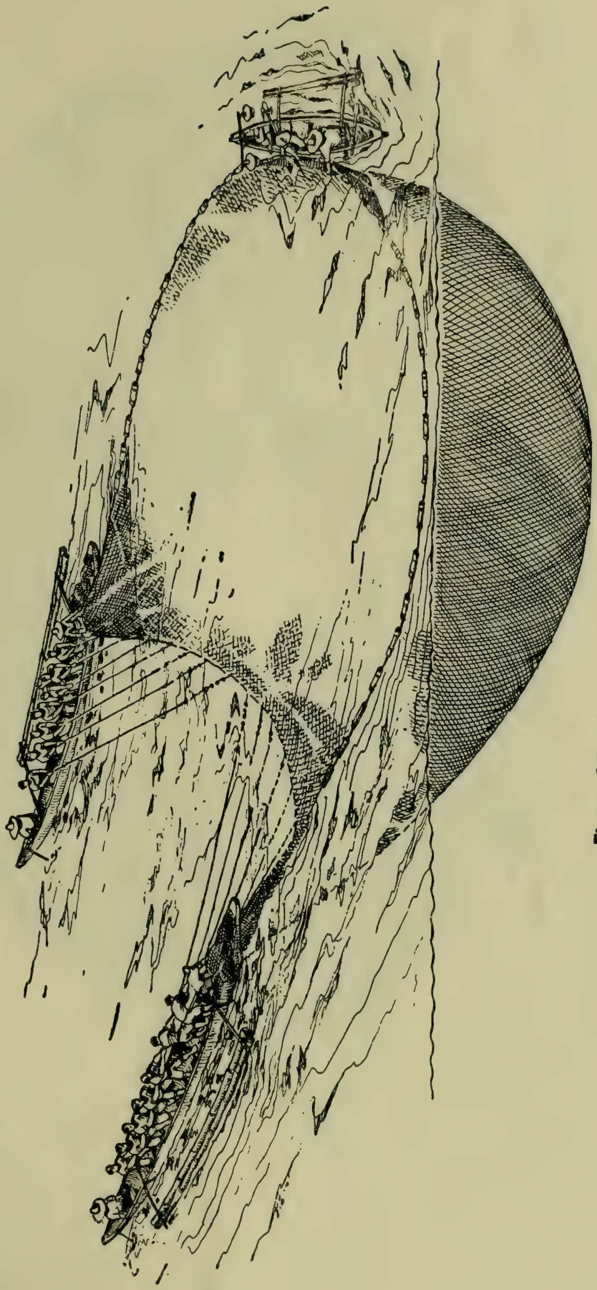

Figure 37.—Sapyaw (Tagalog), a typical round haul seine.

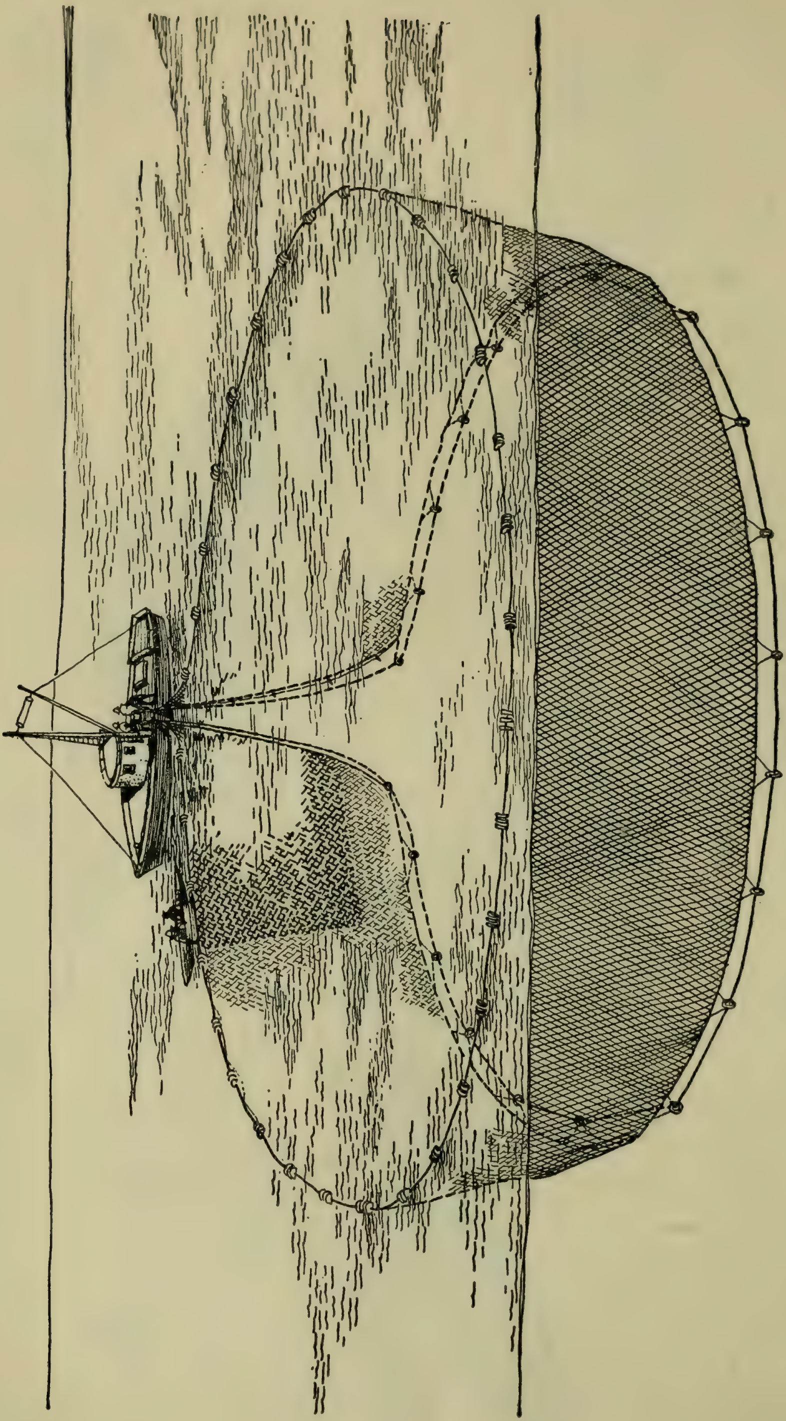

Figure 38.—A purse seine.

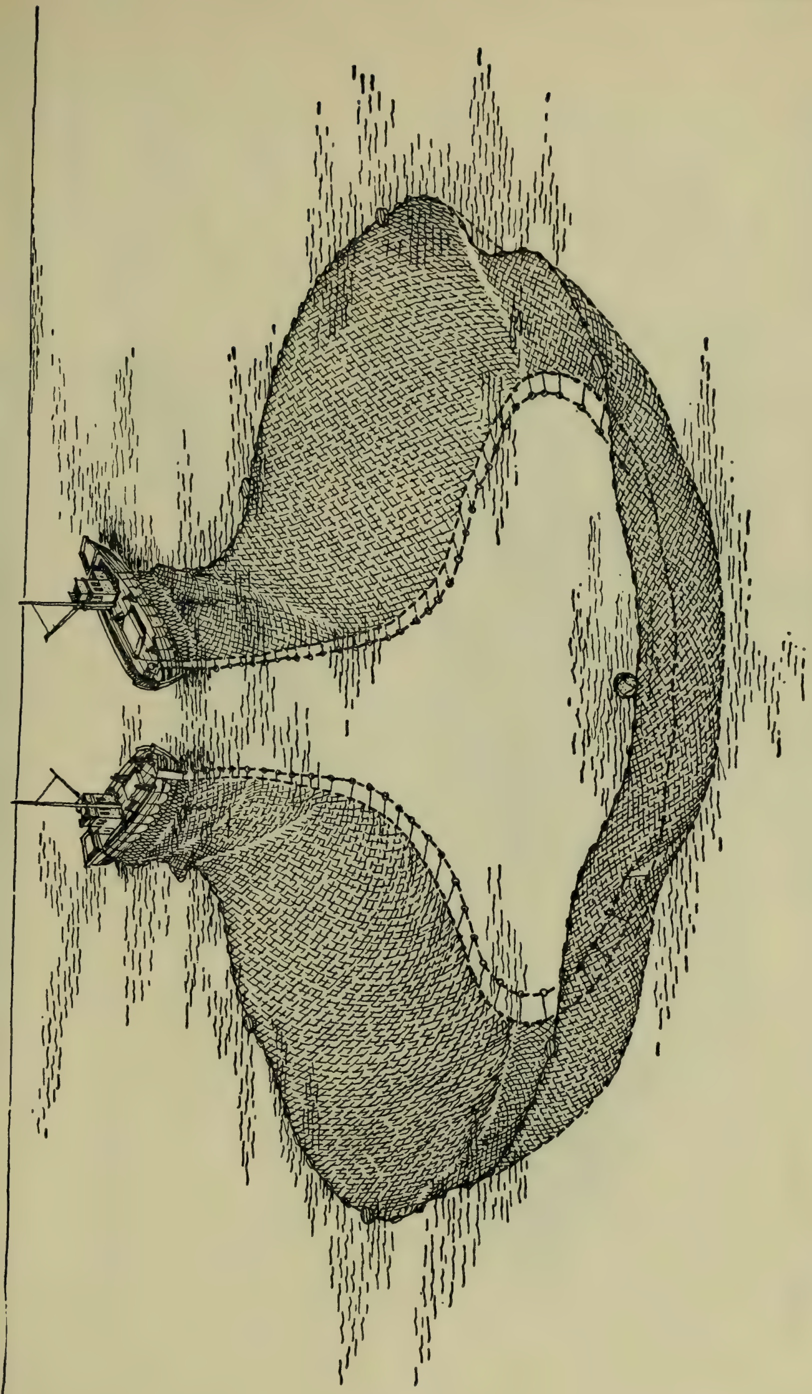

Figure 39.—An example of a ring net in operation.

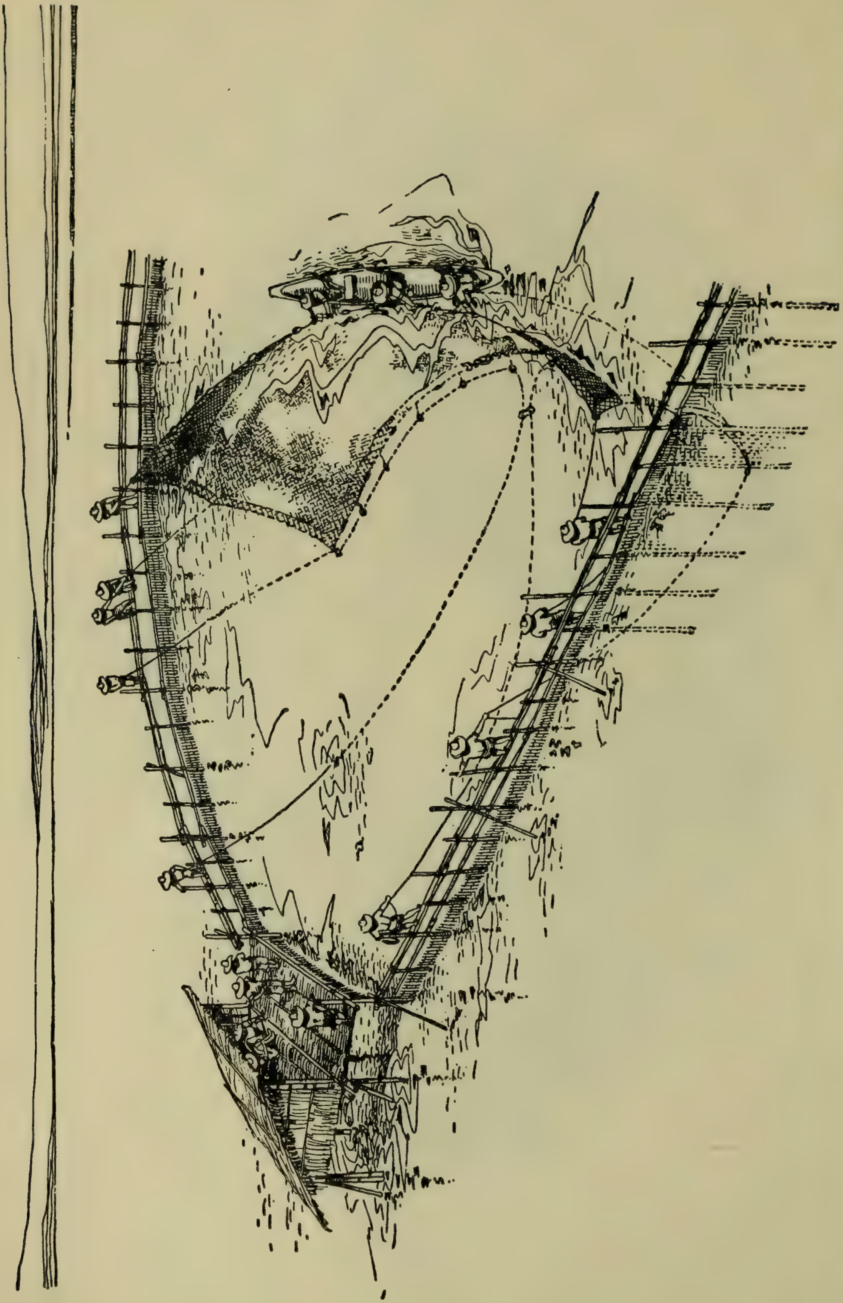

Figure 40.—A scoop seine, gayad (Tagalog) employed in brailing out the catch direct from the semicircular enclosure of deep-water fish corrals.

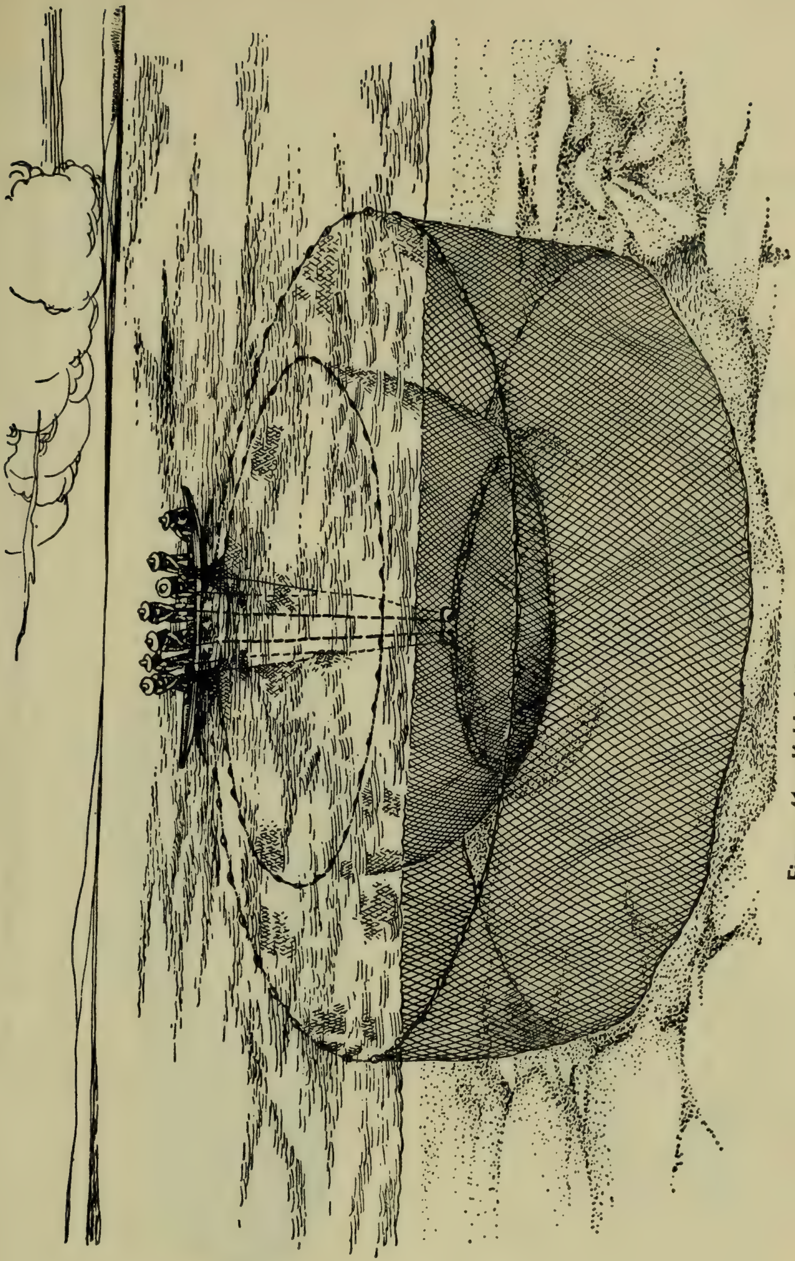

Figure 41.—Kubkob (Bikol), a typical stop seine.

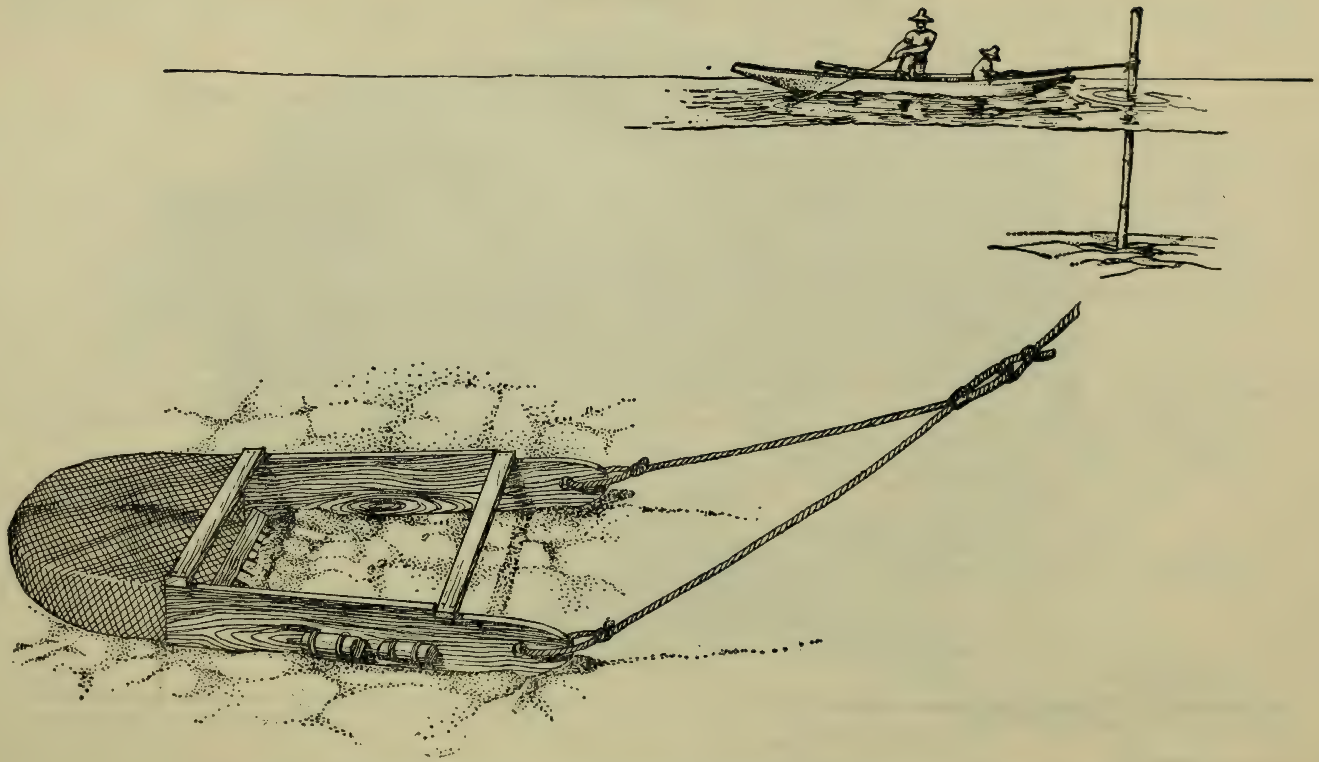

Figure 42.—Kaladkad (Tagalog), a typical dredge net used in collecting shells in central Luzon.

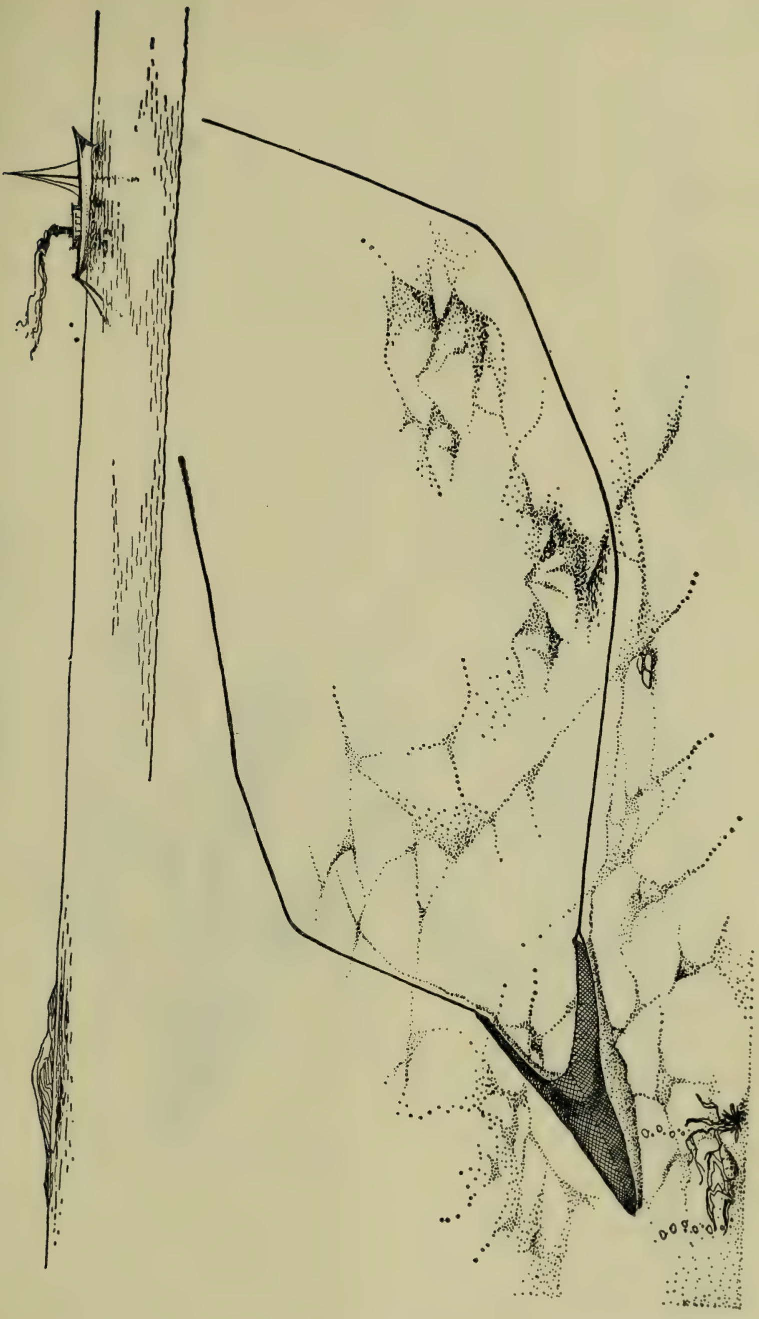

Figure 43.—A Danish trawl.

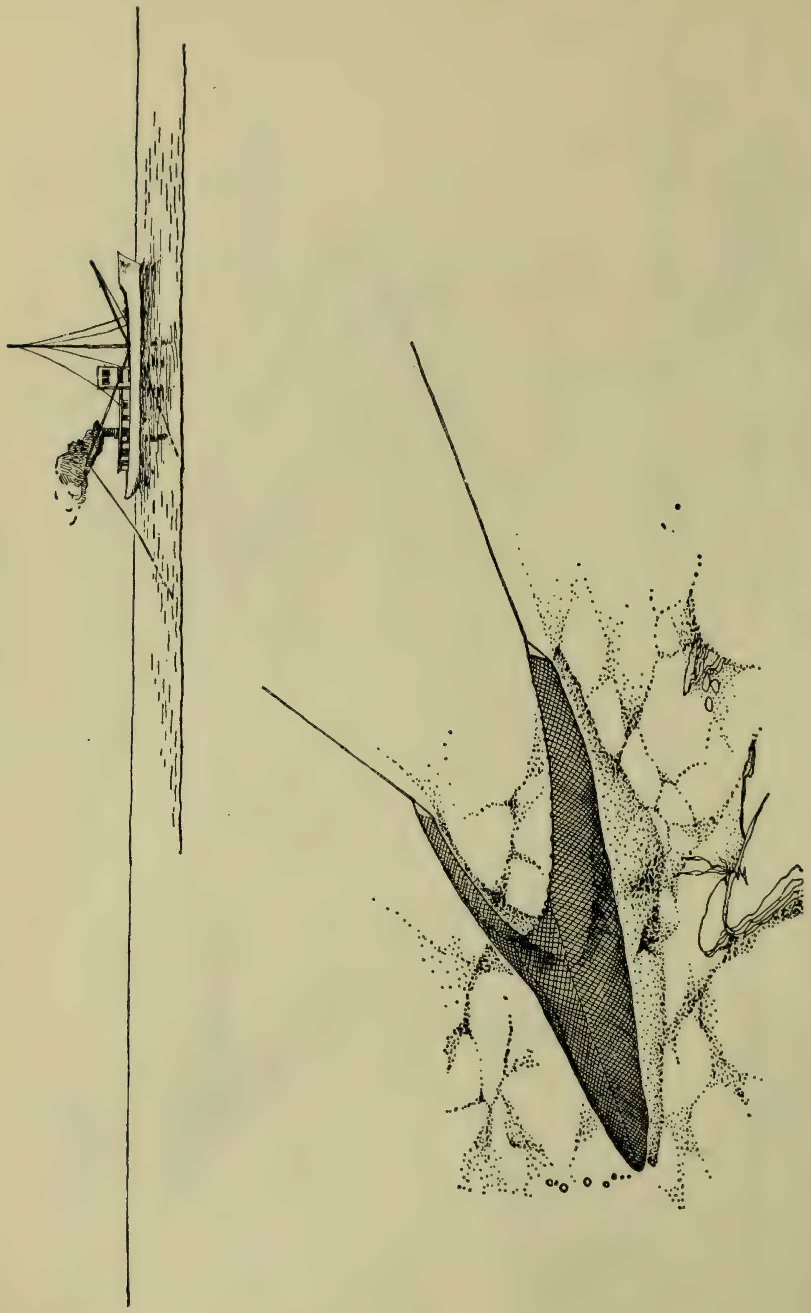

Figure 44.—An Irish trawl.

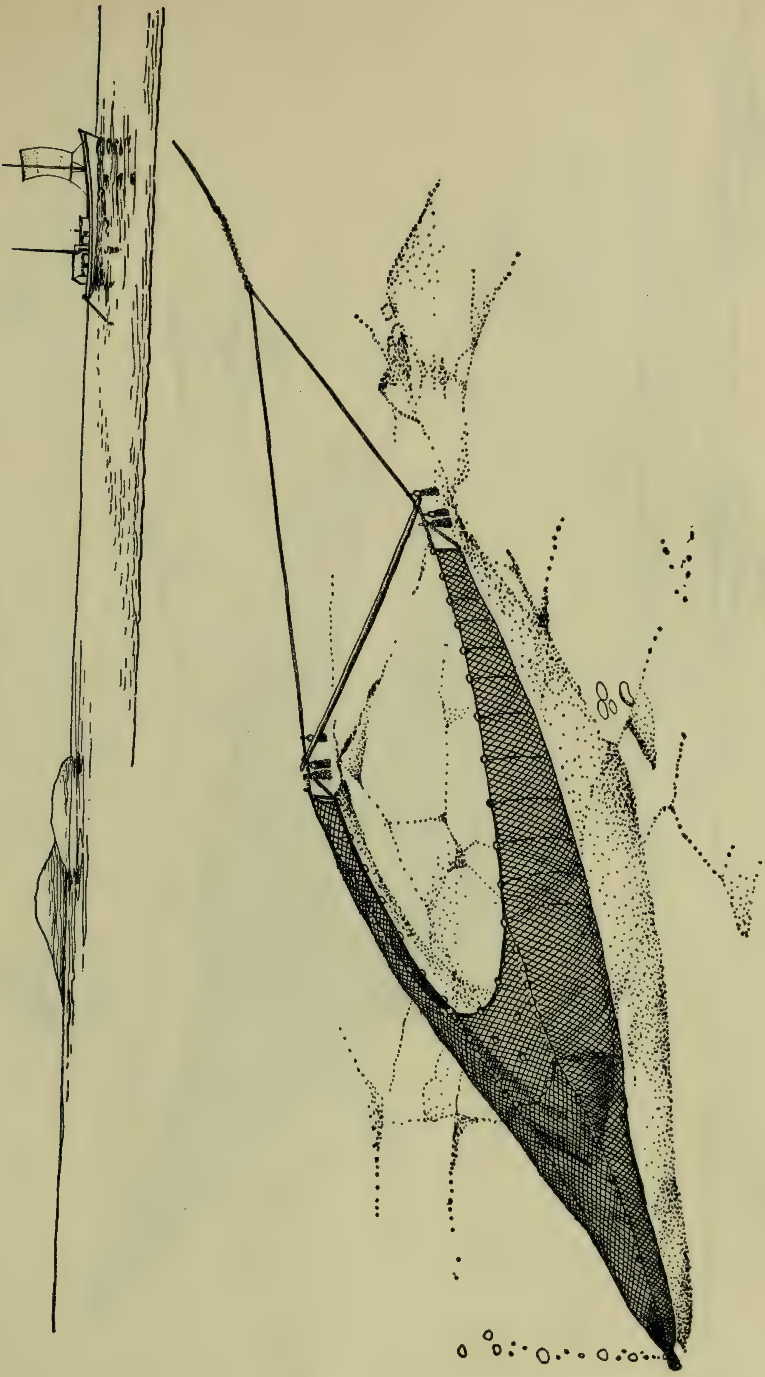

Figure 45.—Utase (Pilipino-Hapones), a Japanese trawl.

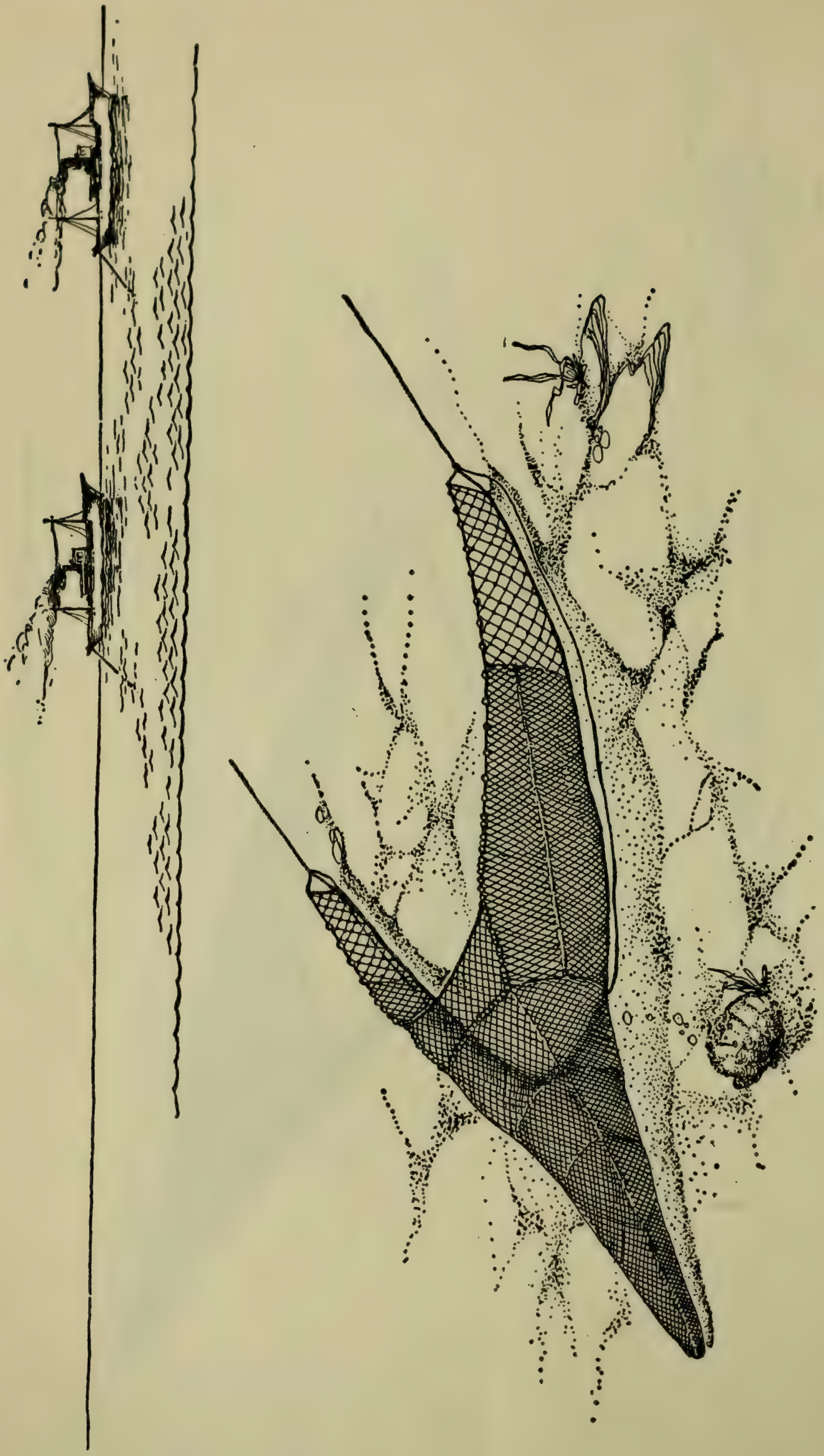

Figure 46.—A Spanish trawl.

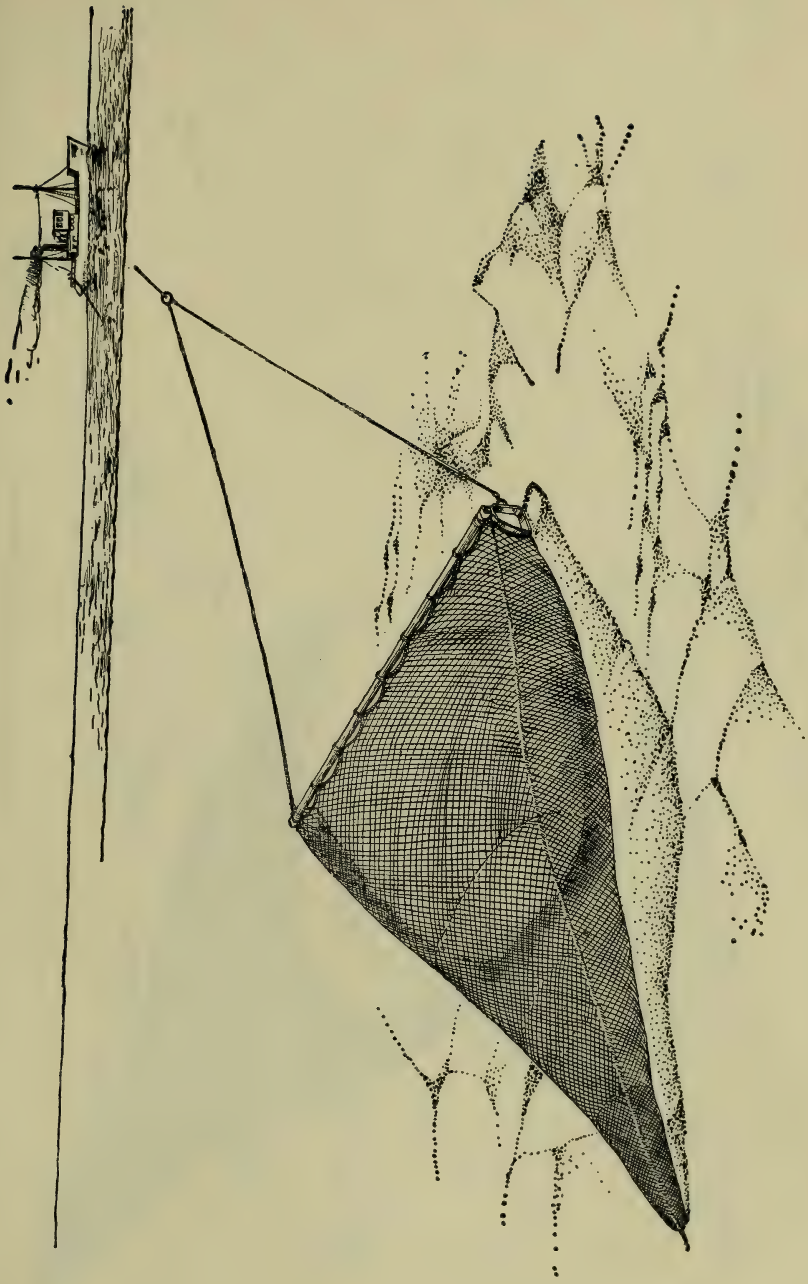

Figure 47.—A typical beam trawl.

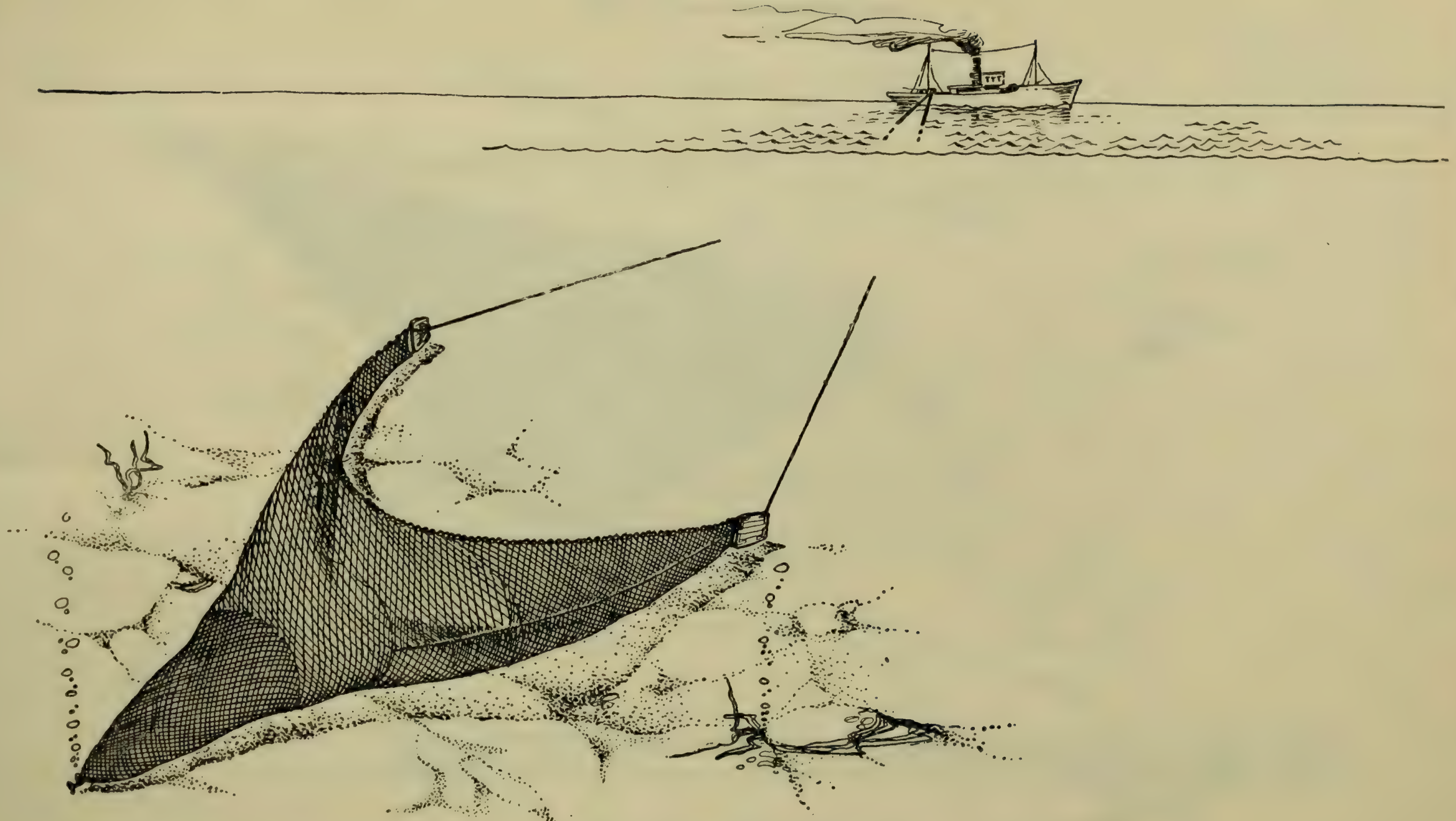

Figure 48.—An ordinary otter trawl.

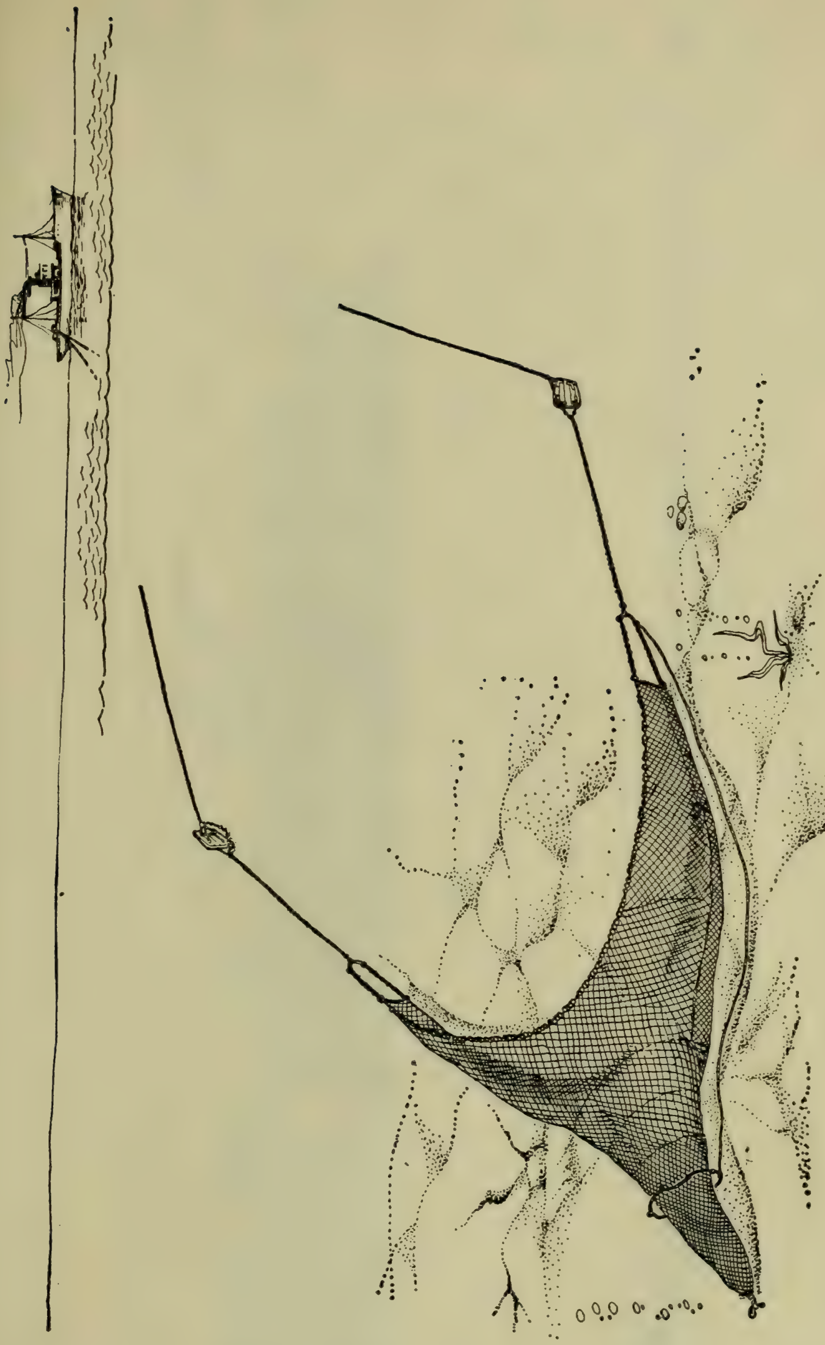

Figure 49.—A Vigneron-Dahl otter trawl.

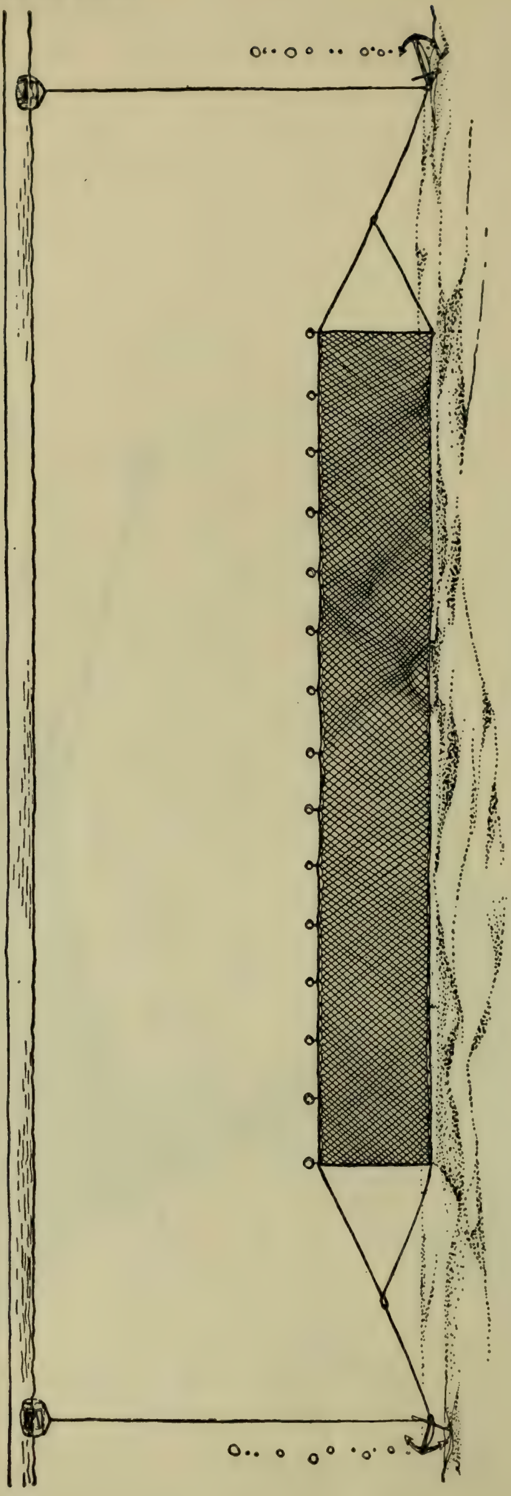

Figure 50.—A set gill net

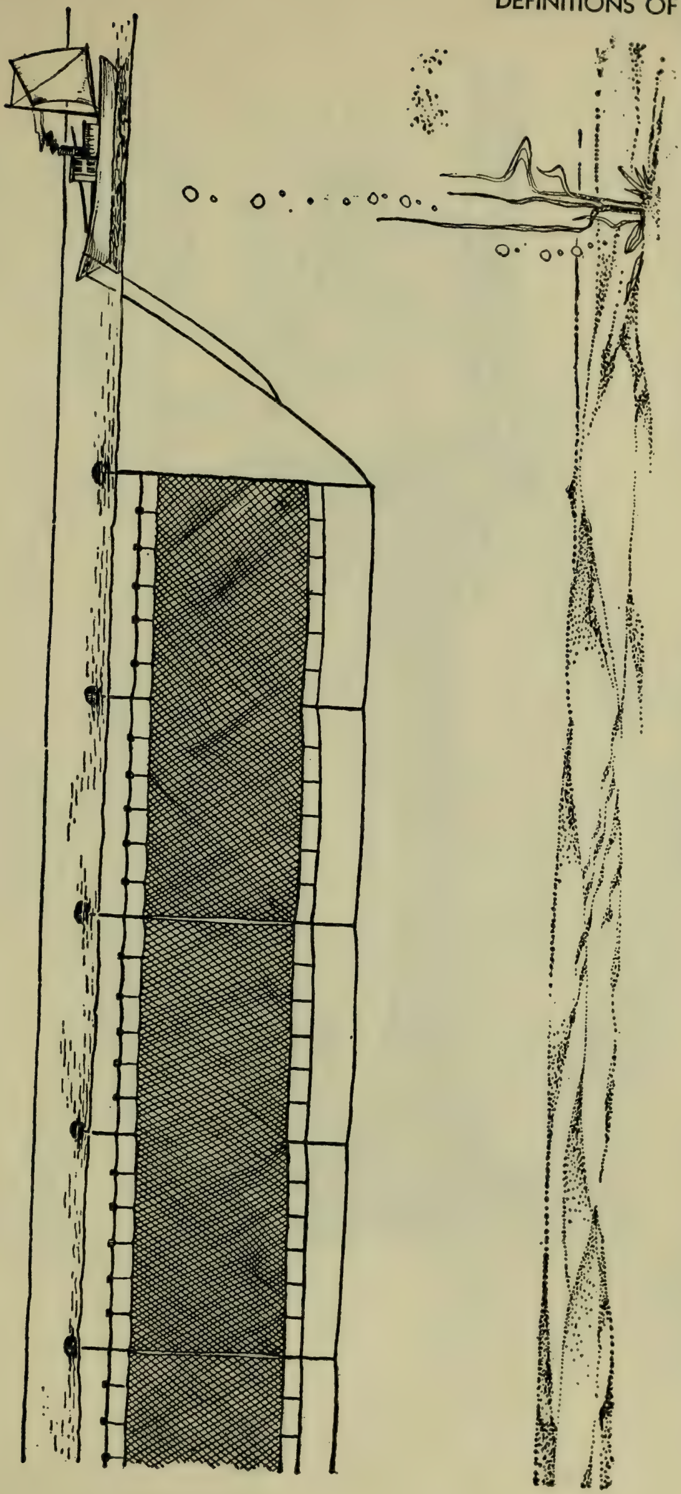

Figure 51.—A drift net.

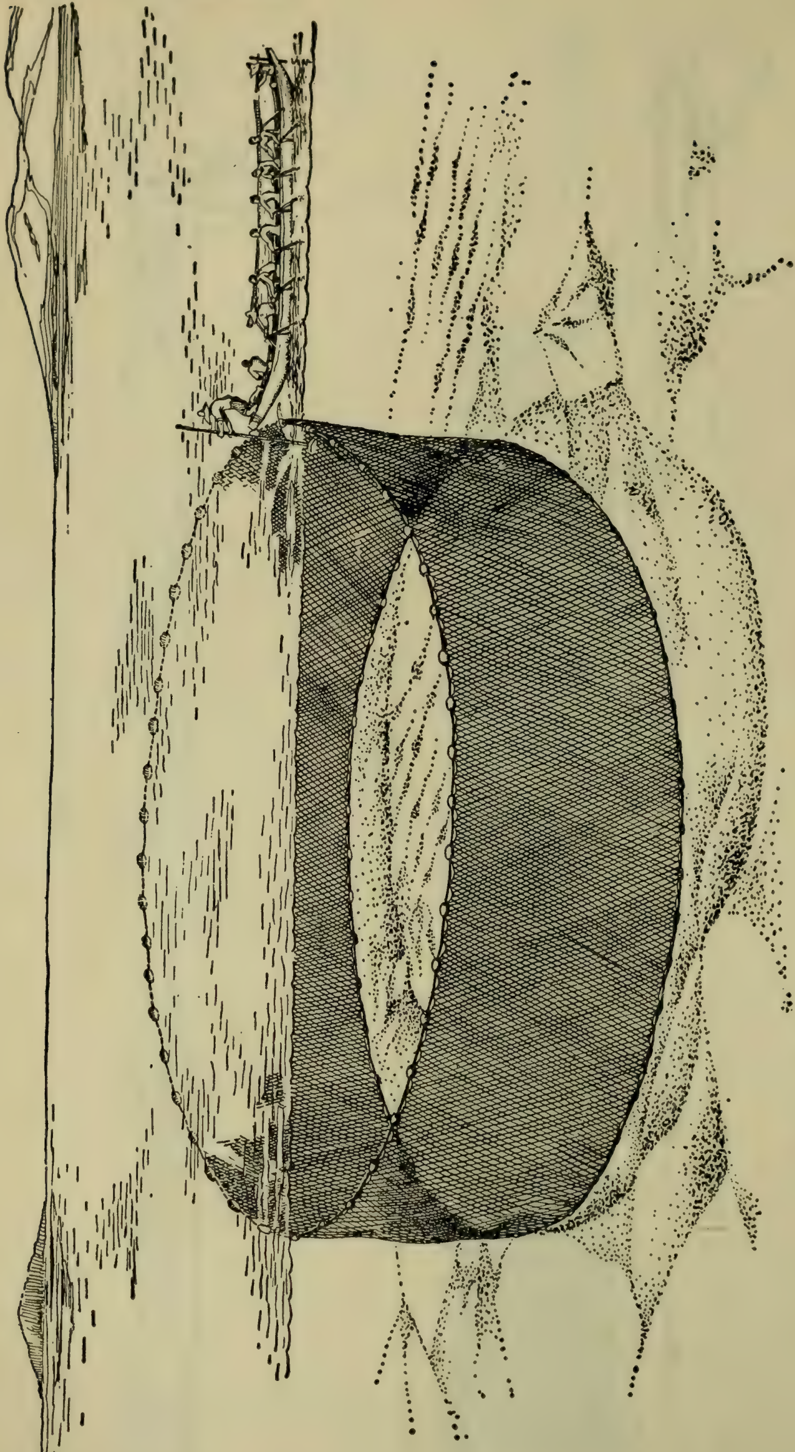

Figure 52.—Bating or halang (Tagalog), a typical encircling gill net for sardines.

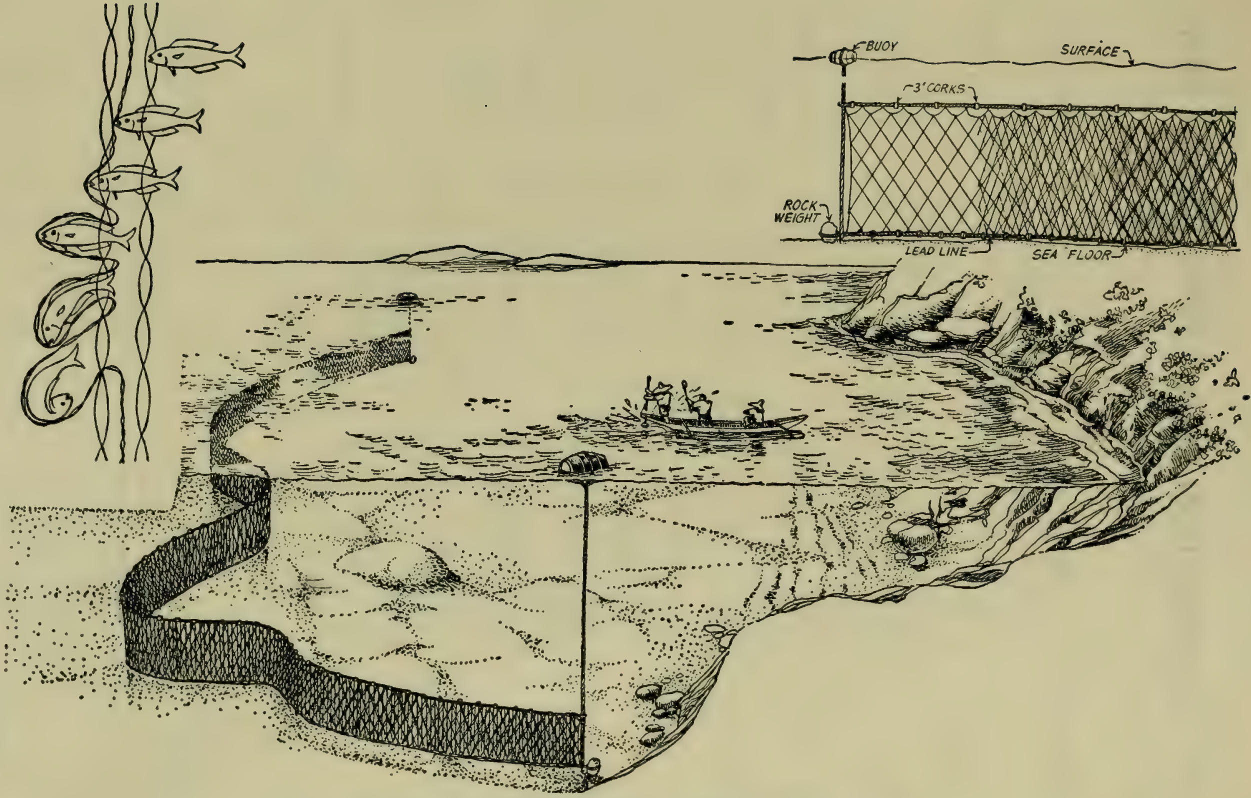

Figure 53.—Trasmaliyo (Pilipino-Spanish), a trammel net.

Part IV. CLASSIFICATION OF PHILIPPINE FISHING GEAR

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
A					
Abang	Tagalog		Fish corral		
Aboy-bating	Bikol				Tuck seine.
Agahid	Samar Bisaya				Drag seine.
Agila	Tagalog Spanish		Fish corral		
Agila-baybayin	do		do		
Agoyan	Iloko		Barricade		Drive-in-net.
Aguyan	do		do		Do.
Alang	Pangasinan				Lever net.
Alas-na-kupas	Bikol-Spanish		Fish corral		
Alkabos	Talagog Spanish	Spear or harpoon.			
Do	Kapampangan-Spanish.	do			
Ale	Sebu Bisaya				Gill net
Amba	Ilongo Bisaya		Barricade		
Ambak	Bikol		Fish corral		
Ambulante	Tagalog-Spanish		do		
Ampas	Bisaya		do		
Ampis	do				Filter net.
Angkla	Tagalog-Spanish		Fish corral		
Anod	Bisaya				Drift net.
Anod-pamili	Maranaw				Do.
Anod-pangawa	Sebu Bisaya				Do.
Ansad	Bikol		Fish corral		
Ansag	Sambal		Barricade		
Do	Bikol		Fish corral		
Antol	Sebu Bisaya		Barricade		
Aplos	do				Drive-in-net.
Aranas	Bisaya-Spanish			Squid jig	
Aranyas	do			do	
Arkabos	Kapampangan-Spanish.	Spear			
Do	Tagalog-Spanish	Spear or harpoon.			
Arikos	Samar Bisaya				Gill net.
Arikos-sa-bato	do				Do.
Arong	do		Fish shelter		
Arpon	Sebu Bisaya-Spanish	Harpoon			
Asad	Iloko	Cover pot			
Asar	do		Barricade		
Asog	Ilongo Bisaya		Fish corral		
Ataraya	Tsabakano				Cast net.
Do	Sebu Bisaya-Spanish				Do.
Ataraya-panamban	do				Do.
Ataraya-pangguno	do				Do.
Atob	Ilongo Bisaya		Barricade		
Atog	do		do		
Atol	Kuyonon		Fish corral		

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
B					
Babaw-on	Ilongo Bisaya		Fish pot		
Babhas	Sebu Bisaya		Fish corral		
Bakikong	Tagalog		Fish potlike trap.		
Baklad	do		Fish corral		
Do	Sambal		do		
Do	Kapampangan		do		
Baklad-alangan	Tagalog		do		
Baklad-bakuod	Batangas Tagalog		do		
Baklad-balango	Kapampangan		do		
Baklad-bukana	Batangas Tagalog		do		
Baklad-gayarin	Tagalog		do		
Baklad-gilid	do		do		
Baklad-laot	do		do		
Baklad-madalang	do		do		
Baklad-malamba	do		do		
Baklad-malimit	do		do		
Baklad-paktang	do		do		
Baklad-paglibis	Kapampangan		do		
Baklad-palapad	Tagalog		do		
Baklad-pandak	Batangas Tagalog		do		
Baklad-pangbukana	do		do		
Baklad-panggilid	Tagalog		do		
Baklad-pang-ilog	Batangas Tagalog		do		
Baklad-pangmalalim	do		do		
Baklad-pangwawa	do		do		
Baklad-pansipit	do		do		
Baklad-salukan	Tagalog		do		
Baklad-salukil	Kapampangan		do		
Baklad-salukin	Tagalog		do		
Baklad-siid	do		do		
Baklad-wawa	do		do		
Baklar	Banton-Bisaya		do		
Bakod	Ilongo Bisaya		do		
Bakusad	do		do		
Bakutot	Tagalog		Fish trap		
Badlas	Sebu Bisaya				Gill net.
Bahan	Bisaya				Drive-in-net.
Do	Samar Bisaya		Fish trap		
Do	Bikol				Drive-in-net.
Bahid	do				Drag seine.
Balahan	Bisaya				Drive-in-net.
Balahan-mora	Sebu Bisaya				Do.
Balahan-pamalo	do				Do.
Balasnig	Samar Bisaya				Bag net.
Balayan	Sebu Bisaya		Fish trap		Do.
Balaybay	Ilongo Bisaya		Fish corral		
Balerong	Sebu Bisaya		do		
Balhin-halhin	do		do		
Balhinon	do		do		
Baling	Bisaya				Drag seine.
Balingad-ngad	Tagalog		Fish corral		
Balingato	Iloko				Hoop net.
Do	Ibanag				Do.
Baling-baling	Sebu Bisaya				Drag seine.
Baling-baling binid-biran	do				Do.

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
Baling-kasaw	Sebu Bisaya				Drag seine.
Baling-lawod	do				Tuck seine.
Baling-lukay	do				Drive-in-net.
Baling-pangbaro-baro	do				Do.
Baling-sa-laod	do				Tuck seine.
Baling-sinsoro	do				Drag seine.
Balirong	do		Fish corral (live box).		
Balisasa	Kapampangan		Fish pot		
Baliwasnan	Tagalog			Pole and line.	
Baliwit	Pangasinan			Handline	
Do	Sambal			do	
Balsa	Bisaya-Spanish		Fish shelter		
Balumbong	Tagalog		Fish trap		
Baluyboy	Iloko		Fish corral		
Banata	Samar Bisaya				Gill net.
Do	Tagalog		Fish corral		
Banata-pukot	Samar Bisaya				Gill net.
Banatas	Sebu Bisaya				Drag seine.
Banate	Ilongo Bisaya		Fish corral		
Ban-ay	Ibanag				Cast net.
Bangkulong	Kapampangan		Fish shelter		
Bangon	Batangas Tagalog		Fish pot		
Banhit	Sebu Bisaya			Handline	
Baniit	Iloko			do	
Do	do			Pole and line.	
Banit	Sambal			do	
Banowit	Pangasinan			Lines	
Bantak	Bisaya		Fish pot		
Do	Iloko			Handline	
Do	do			Pole and line.	
Do	Pangasinan			Longline	
Bantak-igid	Iloko			Pole and line.	
Bantak-taaw	do			Handline	
Banwar	do				Filter net.
Banwar-rinakitan	do				Do.
Banwit	Bikol			Handline	
Do	Pangasinan			do	
Banwit pang-abo	Bikol			Handline	
Barekbek	Iloko		Fish pot		
Barimbaw	Tagalog				Drag seine.
Baring	Samar Bisaya				Do.
Do	Ibanag				Drift net.
Baring-baring	Samar Bisaya				Drag seine.
Baslay	Ilongo Bisaya	Spear			
Baslig	Tagalog				Bag net.
Basnig	Pilipino				Do.
Do	Sebu Bisaya				Round haul seine.
Basnig-likos-hapones	Ilongo Bisaya				Trap net.
Basnig-sulol-an	do				Bag net.
Basnig-tamban	do				Do.
Basursor	Iloko			Longline	

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
Batbating	do				Small drag seine.
Batkwas	Hoko			Handline	
Batikong	do		Barricade		
Batikungkong	do		do		
Bating	Tagalog				Gill net.
Batok	Iloko				Small drag seine.
Bayaba	Sebu Bisaya		Fish corral		
Bayakos	Kapampangan				Filter net.
Bayakos	Batangas Tagalog				Drag seine.
Bayakos-pangbanka	do				Do.
Bayakos-panggilid	do				Do.
Baykos-panlakad	do				Do.
Bayot	Iloko				Push net.
Bentoy	Banton Bisaya				Crab lift net.
Bentoyl	Aklan Bisaya				Do.
Besig	Sebu Bisaya		Barricade		
Better	Iloko		do		
Bibedol	Samar Bisaya	Spear			
Bikatot	Tagalog		Fish pot		
Bidyo	Sebu Bisaya	Spear			
Bigyo	do	do			
Binalinduko	Samar Bisaya		Fish corral		
Binaterol	do		do		
Bingit	Taw Sug			Handline	
Do	Samal			do	
Bingwit	Maranaw			Pole and line.	
Bintol	Pilipino				Crab lift net.
Binwit	Tagalog			Pole and line	
Biray	Iloko				Drag seine.
Biray-kon-daklis	do				Do.
Bisig	Bisaya		Barricade		
Bitana	Bikol				Drag seine.
Do	Bisaya				Do.
Bitay	Ilongo Bisaya			Pole and line.	
Bithay	Batangas Tagalog	Scoop			
Bitinan	Tagalog				Dip net.
Biwas	do			Pole and line.	
Biyakos	Kapampangan				Filter net.
Do	Tagalog				Drag seine.
Biyakos-agila	Kapampangan				Filter net.
Biyakos-alamang	do				Do.
Biyakos-alimit	do		Fish corral		
Biyakos-bolusok	do		do		
Biyakos-labitan	do				Filter net.
Biyakos-palapad	do		Fish corral		
Biyakos-paro	do				Filter net.
Biyaw	Sebu Bisaya				Dip net.
Bokatot	Iloko				Hoop net.
Do	do		Fish pot		
Boholano	Tagalog		Fish corral		
Bolitse	Bikol				Drag seine.
Bombon	Pilipino		Fish shelter		

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
Bonuan	Bisaya		Fish corral		
Do	Sambal		do		
Bonuan-ordinaryo	Samar Bisaya		do		
Bonuan-pahubas	do		do		
Bonuan-palagod	do		do		
Bonuan-simongat	do		do		
Bubo	Pilipino		Fish pot		
Do	Iloko		do		
Bubo-kinaban	Ilongo Bisaya		do		
Bubod	Sebu Bisaya		Fish corral		
Bubo-sa-aniit	Bikol		Fish pot		
Bubo-sa-hipon	Tagalog		do		
Bubo-sa-sira	Bikol		do		
Bukatot	Tagalog		Fish trap		
Do	Iloko				Hoop net.
Do	do		Fish pot		
Bukatot-na-lambat	Tagalog				Hoop net.
Bukatot-na-oway	do		Fish pot		
Budhi	Bisaya		Fish corral		Set impounding net.
Bugkat	Bikol		Fish corral		
Bulos	do	Harpoon			
Bumbon	Tagalog		Fish shelter		
Bumbon-hipon	do		do		
Bungaw	Sebu Bisaya		Fish pot		
Bungsod	Bisaya		Fish corral		
Do	Maranaw		do		
Bunit	Bisaya			Pole and line.	
Do	Aklan Bisaya			do	
Bunsod	Bisaya		Fish corral		
Do	Maranaw		do		
Bunsod-balirong	Sebu Bisaya		do		
Bunsod-binaterol	Ilongo Bisaya		do		
Bunsod-dako	Sebu Bisaya		do		
Bunsod-gamay	do		do		
Bunsod-lapad	do		do		
Bunsod-pahubas	do		do		
Bunsod-paugmad	do		do		
Bunsod-sahid	do		do		
Bunsod-Tinagalog	do		do		
Bunsol	Samal		Fish corral		
Buntog	Samar Bisaya				Gill net.
Bunuan	Bikol		Fish corral		
Do	Samar Bisaya		do		
Bunuan-pahubas	do		do		
Bunuhan	Tagalog		do		
Burayok	Iloko		Barricade		
Busbos	Ibanag				Lift net.
Butas-baklad	Tagalog		Fish corral		
Butong	Sebu Bisaya				Drive-in-net.
Buya	Bikol-Spanish		Fish shelter		
K					
Kabitenyo	Bikol-Spanish		Fish corral		
Kabyaw	Samar Bisaya				Blanket net.
Do	Bikol				Round haul seine.
Kabyaw-kon-luses	Bikol-Spanish				Do.

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
Kabyaw-ha-salog	Samar Bisaya				Lift net.
Kabyaw-ordinaryo	Bikol-Spanish				Round haul seine.
Kakayang	Ivatan				Dip net.
Kafu	Ibanag				Push net.
Kaladkad	Tagalog				Dredge net.
Kalamba	Samar Bisaya				Gill net.
Kalaskas	Kapampangan	Rake			
Do	Iloko		Fish trap (impounding device)		
Do	Pangasinan				Drive-in-net.
Do	Tagalog				Do.
Do	Palanan				Do.
Kalaykay	Tagalog-Bikol	Rake			
Kaligid	Sebu Bisaya		Fish pot		
Kalinawan	do		Fish corral		
Kalong	Ilongo Bisaya				Gill net.
Kalubkob	Sambal		Fish corral		
Kalukor	Pangasinan				Drag seine.
Kamlad	Ilongo Bisaya				Do.
Kammag	Iloko				Do.
Kammang	do				Gill net.
Do	Pangasinan				Do.
Do	Ibanag				Do.
Kansisi	Tagalog				Do.
Kantil	Samal				Tuck seine.
Do	Taw Sug				Do.
Kapit	Tagalog				Push net.
Kapot	Iloko				Do.
Karaynas	do				Drive-in-net.
Karik	Pangasinan			Pole and line.	
Karudkod	Iloko				Drag seine.
Karukal	Kuyonon			Squid jig	
Karukod	Iloko				Drag seine.
Do	Pangasinan				Do.
Karurokod	Ibanag				Do.
Karwas	Iloko	Scoop			
Do	Ibanag	do			
Kasad	Iloko				Lift net.
Kasag	Tagalog				Do.
Do	Iloko				Drive-in-net
Do	Pangasinan				Do.
Kaskasad	Iloko				Lift net
Kaskasag	do				Do.
Kataw	Samar Bisaya			Longline	
Katev	Ivatan		Crab trap		
Katigbi	Tagalog				Drive-in-net.
Kawad	Sebu Bisaya			Line	
Kawag	Ilongo Bisaya			Handline	
Kawil	Pilipino			do	
Kawil-pangpusit	Tagalog			Squid jig	
Kaw-it	Iloko	Gaff			
Do	Sebu Bisaya	do			
Kayakas	Tagalog				Drive-in-net.
Do	Pangasinan				Do.

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
Kayakas-boholano	Tagalog				Drive-in-net.
Kayakay	do				Do.
Kayagkag	Bisaya				Gill net.
Kayagkag-pahubas	Sebu Bisaya				Do.
Kayagkag-pamalo	do				Do.
Kayagkag-pamansi	do				Do.
Kaykag	Ilongo Bisaya				Do.
Kileb	Iloko		Barricade		
Kilo-kilo	Tagalog		Fish corral		
Do	Bikol		do		
Kiming	Kuyonon		Fish pot		
Kimpot	Kapampangan		do		
Kinabite	Bikol		Fish corral		
Kitang	Tagalog			Longline	
Do	Pangasinan			do	
Do	Iloko			do	
Do	Sambal			do	
Kitang-pangkanduli	Tagalog			do	
Kitang-pangdalag	do			do	
Kitay	do			do	
Kiteb	Iloko		Barricade		
Kitid	Kapampangan				Drift net.
Do	Aklan Bisaya				Gill net.
Kitig	Tagalog				Lift net.
Kolorado-koral	Bisaya-Spanish		Fish corral		
Konay	Samar-Bisaya				Drive-in-net.
Do	Sambal				Do.
Konukon	Iloko		Fish shelter		
Do	Ibanag		do		
Konurona	Dabawenyo		Fish corral		
Koral-boholano	Bikol-Tagalog		do		
Kubkob	Bisaya-Tagalog				Purse seine.
Do	Bikol				Stop seine.
Kubkobilyo	Samar Bisaya-Spanish.				Round haul seine.
Kubkob-patiyoy	Bisaya				Do.
Kubkob-simbada	do				Do.
Kubo	Iloko		Fish trap		
Kubong-kubong	do		Fish corral		
Kulakod	Tagalog				Dredge net.
Kulokutok	do				Drive-in-net.
Kulong	Bisaya		Fish trap		
Do	Maranaw		do		
Do	Iloko		Fish shelter		
Kurikan	Batangas Tagalog			Troll line	
Kurokod	Iloko				Drag seine.
Kurokod-partigo	do				Round haul seine.
Kurokutok	Batangas Tagalog				Drive-in-net.
Do	Banton Bisaya				Do.
D					
Dakikong	Tagalog		Fish trap		
Daklis	Iloko				Drag seine.
Do	Pangasinan				Do.
Do	Sambal				Do.
Do	Batangas Tagalog				Gill net.

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
Daklis-a-linas	Iloko				Drag seine.
Daklis-de-ipon	do				Do.
Dagdag	do		Barricade		
Dagukdok	Sebu Bisaya			Handline	
Dagwan	Tagalog		Fish trap		
Da-ing	Kapampangan		Fish pot		
Dala	Tagalog				Cast net.
Dala-pamulanguso	do				Do.
Dala-pang-alangan	do				Do.
Dala-pangbakoko	do				Do.
Dala-pangdalag	do				Do.
Dala-pangduhay	do				Do.
Dala-pangkanduli	do				Do.
Dala-pangsilinyasi	do				Do.
Dala-sundol	do				Do.
Da'lis	Iloko				Drag seine.
Daplak	Ilongo Bisaya		Fish pot		
Daplis	Batangas Tagalog				Drive-in-net.
Darilay	Ibanag			Longline	
Dayakos	Tagalog				Filter net.
Do	do				Drag seine.
Do	Iloko				Dip net.
Dayos	do				Drag seine.
Dayusdos	do				Push net.
Dinumpil	Samar Bisaya		Fish corral		
Dinungpil	do		do		
Diyakos	Tagalog				Filter net.
Dudok	Ivatan				Dip net.
Dugmon	Aklan Bisaya		Fish shelter		
Dulon	Iloko				Drag seine.
Dumaga	Sebu Bisaya		Fish corral		
Dumalaga	do		do		
Dumpil	do		Fish trap and fish corral.		
Dundon	Iloko				Lift net.
Dusdos	do				Push net.
E					
E-erew	Ivatan	Hook			
Ese	Sebu Bisaya	Spear			
Esparabel	Bisaya-Spanish				Cast net.
Do	Ibanag-Spanish				Do.
Etter	Iloko		Barricade		
Etter-pamobuan	do		do		
Etter-panayotan	do		do		
G					
Gakit	Sebu Bisaya		Fish trap		
Galay	Tagalog			Pole and line.	
Gangen	Ibanag		Fish pot		
Gango	Sebu Bisaya				Gill net.
Garamgam	Iloko				Drag seine.
Garemgem	Iloko				Do.
Garong	Sebu Bisaya				Blanket net.

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
Gayad	Tagalog				Scoop seine.
Do	Sambal				Do.
Gayang	Ivatan	Spear			
Genned-palagto	Iloko				Lift net.
Ginantso	Samar Bisaya				Gill net.
Gulgo	Sebu Bisaya		Fish shelter		
Gulgol	Samar Bisaya				Drag seine.
Gulgol-sa-anga	Sebu Bisaya		Barricade		
Gulgol-sa-igdidili	do				Filter net.
Guma	Samar Bisaya		Fish shelter		
Guyod	Sebu Bisaya			Troll line	
H					
Habay	Tagalog			Longline	
Habing-ng-dulong	do		Fish trap		
Habog	Samar Bisaya		Fish corral		
Halakob	Sambal		Cover pot		
Halang	Tagalog				Gill net.
Do	do				Drag seine.
Hampas	Bisaya		Fish shelter		
Hampas lag-e	Sebu Bisaya		Fish corral		
Hangpas	do		Fish shelter		
Hanig	Bisaya				Drive-in-net.
Hapin	Tagalog			Lines	
Hapon	Taw Sug			do	
Do	Samal			do	
Harpon	Sebu Bisaya-Spanish	Spear			
Hasang-antigo	Ilongo Bisaya-Spanish		Fish corral		
Hasang-moderno	do		do		
Hasang-simple	do		do		
Hayhay	Batangas Tagalog			Longline	
Hibasan	Tagalog		Barricade		
Hikog	Aklan Bisaya	Snare			
Hiktas	Samar Bisaya		Fish corral		
Hiir	Sambal		Fish pot-like trap.		
Hila-hila	Kapampangan				Drag seine.
Do	Tagalog				Do.
Do	Ilongo Bisaya			Squid jig	
Hukog	Sebu Bisaya		Fish corral		
Hud-hod	Bisaya				Push net.
Do	Bikol				Do.
Hug-hog	Sebu Bisaya			Handline	
Hulod	Samar Bisaya		Fish corral		
Hulog-hulog	Sebu Bisaya			Handline	
Hulyang	Sambal		Barricade		
Huyod	Sebu Bisaya		Fish corral		
I					
Ililikos	Sebu Bisaya				Drag seine.
Inangkla	Bisaya		Fish corral		
Do	Bikol		do		
Ingog-bahan	Sebu Bisaya				Long haul seine.
Isol-isol	Kuyonon				Drive-in-net.
Do	Tagbanwa				Do.
Ivoya-sakag	Ivatan				Push net.
Iwag	Ilongo Bisaya				Round haul seine.

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
L					
Labang	Sebu Bisaya		Barricade		
Labay	Ilongo Bisaya			Longline	
Laklak	Sebu Bisaya				Trap net.
Lagi	do		Fish corral		
Lagpit	Ilongo Bisaya		Fish trap		
Lala	Sambal				Cast net.
Do	Pangasinan				Do.
Lama	do		Fish shelter		
Lamba	Ilongo Bisaya				Gill net.
Lambat	do				Purse seine.
Lambay	do		Barricade		
Lambo	Bisaya			Drop line	
Do	Samal			do	
Lambonin	Taw Sug		Fish pot		
Do	Samal		do		
Lampara	Bisaya-Spanish				Bag net.
Lampara-kon-sigpaw	Sebu Bisaya Spanish				Dip net.
Langbat	Samar Bisaya				Purse seine.
Lantaw	Samal				Gill net.
Do	Taw Sug				Do.
Lantaw-kasig	Tsabakano				Drift net.
Lantay	Sebu Bisaya		Fish trap		
Lapak	Ilongo Bisaya		Fish corral		
Lapad	Samar Bisaya		do		
Largarete	Tagalog Spanish				Gill net.
Latule-patule	Pangasinan			Pole and line.	
Lawag	Samar Bisaya				Round haul seine.
Lawin	Iloko			Pole and line.	
Lawing	do			do	
Lawiswis	Tagalog	Rake			
Laya	Bisaya				Cast net.
Do	Bikol				Do.
Laya-bintay	Aklan Bisaya				Do.
Laya-pamalanak	Samar Bisaya				Do.
Laya-pamasayan	do				Do.
Laya-panabangongo	do				Do.
Laya-panamban	Sebu Bisaya				Do.
Laya-pankikiro	Samar Bisaya				Do.
Laya-panilag	do				Do.
Laya-panilot	Sebu Bisaya				Do.
Layrong	Ilongo Bisaya		Barricade		
Legma	Pangasinan		Fish shelter		
Lellen	Iloko		Barricade		
Leynete	Sebu Bisaya		Fish corral		
Liay	Ilongo Bisaya				Drive-in-net.
Libas	Sebu Bisaya			Lines	
Libot	Bikol-Tagalog				Drag seine.
Likom-likom	Sebu Bisaya				Do.
Likos	Ilongo Bisaya				Do.
Ligkop	Samar Bisaya				Reef seine.
Lilang	Ilongo Bisaya				Gill net.
Lilep	do	Spear			
Lima	Pangasinan		Fish shelter		

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
Limpot	Tagalog				Filter net.
Linagkaw	Sebu Bisaya		Fish corral		
Linati	Ilongo Bisaya		do		
Linge	Taw Sug				Gill net.
Do	Samal				Do.
Do	Aklan Bisaya				Lift net.
Linge-balo	Tsabakano				Drift net.
Linge-pamalanak	do				Gill net.
Lingi	Bisaya				Drag seine.
Linuyot	Samar Bisaya		Fish corral		
Linya	Tagalog Spanish		do		
Liwliw	Iloko			Pole and line.	
Loy-loy	Sambal			Handline	
Lukayan	Sebu Bisaya				Drive-in-net.
Lukob	Bisaya		Fish corral		
Do	Maranaw		do		
Lukon-lukon	Ilongo Bisaya			Squid jig	
Lukot-anod-pamarungoy	Sebu Bisaya		Fish corral		
Lugo	Samal		Barricade		
Do	Maranaw		do		
Luma	Sambal		Fish shelter		
Lumpot	Tagalog				Filter net.
Lungga	do		Fish shelter		
Lun-oy	Bikol			Troll line	
Luob	Ilongo Bisaya				Trap net.
Luong	Tagalog		Fish shelter		
Luyaw	Iloko				Push net.
M					
Malamba	Tagalog		Fish corral		
Malawa	Samar Bisaya				Gill net.
Mamuno	Ivatan	Spear			
Mamurak	Iloko		Fish shelter		
Manarop-alamang	Pangasinan				Push net.
Manoay-ivoya	Ivatan				Do.
Manoay-masin	do				Do.
Medya	Bisaya-Spanish		Fish corral		
Minata	Sebu Bisaya		Fish trap		
Moro-bahan	do				Drive-in-net.
Moro-pangaling	do		Fish pot		
Muro-ami	Pilipino-Hapones				Drive-in-net.
N					
Nanaw	Bisaya	Spear			
Nasa	Iloko-Spanish		Fish pot		
Do	Tsabakano		do		
Natural	Bisaya-Spanish				Gill net.
Do	Bikol-Spanish		Fish corral		
Noh	Samal	Spear			
O					
Odaod	Iloko				Lift net.
Ordinaryo	Bikol-Spanish		Fish corral		
Osok	Sebu Bisaya		Fish shelter		

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
P					
Paabong	Samar Bisaya				Gill net.
Paadag	Iloko			Pole and line.	
Paandap	do				Cast net.
Paanod	Bisaya				Gill net.
Do.	Tagalog				Do.
Paayas	Iloko		Barricade		
Pabahaan	Aklan Bisaya		Fish corral		
Pabahay	Tagalog		do		
Pabhas	Bisaya		do		
Pabhas-de-salap	Bikol-Spanish				Filter net.
Pakaladkad	Tagalog				Dredge net.
Pakaralet	do		Fish corral		
Pakpak	Pangasinan				Gill net.
Pakpet	do		Fish shelter		
Paktad	Sebu Bisaya		Fish corral		
Paktang	Tagalog		do		
Pakulod	Iloko				Filter net.
Padait	do		Barricade		
Padal	Ibanag		Fish pot		
Padaldal	Iloko		Barricade		
Padapoan	Bikol		Fish shelter		
Padarisdis	Iloko				Drive-in-net.
Padlas	Samar Bisaya				Gill net.
Padlas-panglambiyaw	do				Do.
Padugmon	Aklan Bisaya		Fish shelter		
Padumog	Sebu Bisaya				Gill net.
Padusmog	do				Drag seine.
Paduyan	Bisaya				Blanket net.
Paed	Iloko		Barricade		
Pagataw	do	Spear			
Pagawid	Aklan Bisaya			Longline	
Pagbabahaan	Samar Bisaya		Barricade		
Pagsamban	Iloko		do		
Paguloy	Sambal			Troll line	
Paguyod	Samar Bisaya			do	
Do.	Iloko			do	
Pahabog	Bisaya				Cast net.
Pahanong	Sebu Bisaya		Fish shelter		
Pahibas	Tagalog		Fish corral		
Pahila	do			Troll line	
Do.	Aklan Bisaya			do	
Pahinas	do			do	
Pahubas	Bisaya		Fish corral		
Pahubas-inangkla	Samar Bisaya		do		
Pahunas	Aklan Bisaya		Barricade or fish corral.		
Do.	Bisaya		Fish corral		
Pahunas-inangkla	Samar Bisaya		do		
Pahutik	do		do		
Pailig	Bisaya				Gill net.
Do.	Aklan Bisaya		Barricade		
Pailigan	Samar Bisaya		do		
Palaan	Bisaya		Fish corral		
Palaan-bulonan	Aklan Bisaya		do		
Palaan-tulis	do		do		

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
Palabo	Sebu Bisaya		Fish corral		
Palabay	do.				Gill net.
Palakad	Aklan Bisaya				Push net.
Palagod	do.		Fish corral		
Palamag	Iloko		Fish shelter		
Palanaan	Samar Bisaya		Fish pot		
Palanaan-balawis	Sebu Bisaya		do.		
Palangre	do.			Longline	
Palangre-de-Moro	do.			Troll line	
Palaoy	Iloko			Handline	
Palapad	Tagalog		Fish corral		
Do.	Kapampangan		do.		
Palapad-baklad	Tagalog		do.		
Palapad-lambat	do.				Trap net.
Palaway	Iloko			Longline	
Palayaw	do.		Barricade		
Palayaw-ambulante	Iloko-Spanish		do.		
Palayaw-puwesto	do.		do.		
Palaylay	Pangasinan				Drag seine.
Pal-eg	Iloko		Fish trap		
Palhag	Aklan Bisaya		Fish corral		
Palibong	Tagalog		do.		
Palibtok	Iloko		Barricade		
Paliwliw	do.			Pole and line.	
Palned	do.				Gill net.
Paloay	do.			Longline	
Palseb	do.			Pole and line.	
Palsiit	do.			do.	
Paluay	Tagalog			Longline	
Palubo	Pangasinan				Drive-in-net.
Palubog	Bikol				Gill net.
Do.	Samar Bisaya				Do.
Palubog-mayor	Bikol-Spanish				Do.
Palubog-minor	do.				Do.
Palubog-pangkiskisan	Bikol				Do.
Palubog-sa-balanak	do.				Do.
Palubog-sa-kabasi	do.				Do.
Palubog-sa-kiskisan	do.				Do.
Palubog-sa-lawihan	do.				Do.
Palubog-sa-tabangongo	do.				Do.
Palubog-sa-tamban	do.				Do.
Palukso	Tagalog		Fish corral		
Do.	Sebu Bisaya				Trap net.
Do.	Pangasinan		Barricade-fish trap.		
Paluksohan	Sebu Bisaya		do.		
Do.	Tagalog		Fish corral		
Palumpat	Ilongo Bisaya	Rake			
Paluob	do.		Fish trap		
Paluway	do.			Pole and line.	
Palurop	Sebu Bisaya				Tuck seine.
Palutaw	do.			Line	
Paluyot	do.		Fish corral		
Pamalanak	Pangasinan				Drive-in-net.
Pamalangsi-likos	Sebu Bisaya				Drag seine.

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
Pamalaw	Bikol				Drag seine.
Pamalibtokan	Iloko		Barricade		
Pamaliling	Sebu Bisaya				Gill net.
Pamaling	do				Drag seine.
Pamalo	do				Gill net.
Pamalos	Tagalog	Gaff			
Pamana	Maranaw	Spear			
Do	Bisaya	do			
Pamangkaw	Tagalog				Dip net.
Pamanggal	Sebu Bisaya		Fish pot		
Pamangsi	do				Gill net.
Pamansikol	do			Handline	
Pamantak	do		Fish pot		
Pamarungoy	do				Purse seine.
Pamasayan	Bikol		Fish corral		
Pamataw	Sebu Bisaya			Line	
Pamilis	Iloko				Gill net.
Pamingwit	Sebu Bisaya			Line	
Pamitana	Banton Bisaya			Handline	
Pamitin	Tagalog			Pole and line.	
Pamobuan	Iloko		Barricade		
Pamonit	Aklan Bisaya			Pole and line.	
Do	Banton Bisaya			do	
Pamulanguso	Tagalog				Cast net.
Pamulinaw	do		Barricade		
Pamungbong	Sebu Bisaya				Gill net.
Pamuntonan	do			Line	
Pamuraw	do				Gill net.
Pamuraw-buraw	do				Purse seine.
Pana	Tagalog	Spear			
Do	Iloko	do			
Do	Bisaya	do			
Do	Bikol	do			
Do	Ivatan	do			
Panabit	Kuyonon			Squid jig	
Panabol	Bisaya				Gill net.
Panak	do		Fish pot		
Do	Sebu Bisaya		do		
Panakab	do	Cover pot			
Panak-alimango	Kuyonon		Fish pot		
Panaklob	Tagalog				Cover net.
Panada	Bikol		Barricade		
Panadlas	Sebu Bisaya				Drag seine.
Panagap	Tagalog				Do.
Panagat	Bikol			Handline	
Do	Aklan Bisaya			do	
Do	Kuyonon				Drag seine.
Do	Sebu Bisaya	Gaff			
Panalibot	do				Gill net.
Panalikop	Batangas Tagalog				Ring net.
Panalipot	Ilongo Bisaya		Fish shelter		
Panambakol	Batangas Tagalog				Ring net.
Panamban	Tagalog				Cast net.
Do	Sebu Bisaya				Gill net.
Panamban-palong-palong	do				Bag net.

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
Panaon	Aklan Bisaya		Barricade		
Panara	Bikol				Gill net.
Panarukoy	Iloko				Do.
Panaruyan	Ivatan			Pole and line.	
Panawasig	Sebu Bisaya				Gill net.
Panki	Bikol				Do.
Do	do				Drag seine.
Pandomuot	Sebu Bisaya		Fish corral		
Panera	Bisaya-Spanish		do		
Panga	Aklan Bisaya	Hook			
Pangabasi	Iloko				Gill net.
Do	Bikol				Do.
Do	Kampampangan				Do.
Pangaber	Iloko				Do.
Pang-aber	do				Do.
Pang-agwas	Sebu Bisaya-Spanish				Do.
Pangahig	Tagalog	Rake or dredge.			
Pangal	Maranaw		Fish pot		
Pang-alang-alang	do		Fish corral		
Do	Bisaya		do		
Pang-alangan	Tagalog				Cast net.
Pang-alimasag	do				Drift net.
Pangaling	Aklan Bisaya				Drive-in-net.
Pang-aliso	Iloko				Gill net.
Pang-apta	Batangas Tagalog				Push net.
Pangasag	Aklan Bisaya	Spear			
Pang-asohos	Tagalog				Gill net.
Pangaw	Sebu Bisaya		Fish pot		
Pang-awa	Samar Bisaya				Gill net.
Do	Iloko				Do.
Pangawil	Tagalog			Handline	
Do	Aklan Bisaya			do	
Pangay	do		Fish pot		
Pangbakoko	Tagalog				Cast net.
Do	do				Gill net.
Pangdomudot	Sebu Bisaya		Fish corral		
Pangdugarog	Tagalog				Gill net.
Pangdulis	Batangas Tagalog				Drag seine.
Pangduhay	Tagalog				Cast net.
Pangdulong	do		Fish trap		
Panggal	Bisaya		Fish pot		
Panggalato	Samar Bisaya		Fish corral		
Do	Bikol		do		
Panggalatok	Palanan		do		
Panggay	Aklan Bisaya		Fish pot		
Panggilid	Bisaya				Purse seine.
Panggutob	Sebu Bisaya			Lines	
Panghalubaybay	Tagalog				Cast net.
Panghaol-haol	Sebu Bisaya				Gill net.
Panghasa-hasa	Tagalog				Ring net.
Panghilot	Bukidnon	Snare			
Panghipon	Tagalog		Fish corral		
Panghoya	do				Gill net.
Pang-igat	do	Gaff			
Pang-ilak	Sebu Bisaya	Spear			
Pang-ilaw	do				Push net.

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
Pang-isan	Sebu Bisaya			Lines	
Panglambang	Tagalog				Gill net.
Panglamok	do				Cast net.
Panglawlaw	Tagalog				Gill net.
Panglinte	Bisaya	Spear			
Pangluob	Tagalog		Fish trap		
Panglumayagan	Sebu Bisaya	Spear			
Panglurop	Bisaya	do			
Panglusong	Tagalog				Gill net.
Pangmanamsi	Batangas Tagalog				Drag seine.
Pangorita	Iloko	Spear			
Pangsanga	Sebu Bisaya	Harpoon			
Pangsilinyasi	Tagalog				Cast net.
Pangsulo	Bisaya	Spear			
Pangtamban	Bikol				Gill net.
Pangti	Samar Bisaya				Drift net.
Pangtrukos	Kabitenyo				Tuck seine.
Pangtunsoy	Tagalog				Cast net.
Pangtukos	do				Tuck seine.
Pang-ugnat	do				Drive-in-net.
Pangulong	do				Stop seine.
Pangutob	Sebu Bisaya			Handline	
Panibid	Ilongo Bisaya			Troll line	
Panilay	Batangas Tagalog			Handline	
Panilo	Bikol-Tagalog				Dip net.
Panilot	Sebu Bisaya		Fish corral		
Paniming	do		Fish pot		
Panindaw	Aklan Bisaya				Crab lift net.
Do	Ilongo Bisaya				Do.
Paningahan	Tagalog				Gill net.
Panintak	Maranaw			Pole and line.	
Panira	Bisaya-Spanish		Fish corral		
Panirikinya	do				Gill net.
Panlamba	Sebu Bisaya				Drag seine.
Panlukob	do		Fish corral		Set impounding net.
Panti	Pilipino				Gill net.
Panti-hila-hila	Tagalog				Do.
Panti-malamba	do				Do.
Panti-panapulok	do				Do.
Panti-pangibas	do				Do.
Panting-anod	Bikol-Tagalog				Drift net.
Do	Tagalog				Do.
Panting-lawlaw	do				Gill net.
Panting-palipad	do				Drift net.
Panting-pang-alimasag	do				Do.
Panting-pangbanak	Batangas Tagalog				Gill net.
Panting-pangkanduli	Tagalog				Gill net.
Panting-pangdalag	do				Do.
Panting-pangdangat	do				Do.
Panting-panglumahan	do				Do.
Panting-pangmanamsi	do				Do.
Panting-pangtagan	do				Do.
Panting-pangtanigi	do				Do.
Panting-pukot	do				Drag seine.
Panti-pang-alimasag	do				Drift net.
Panti-pangbakoko	do				Do.

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
Panti-panglumahan	Tagalog				Drift net.
Panti-pangsabalo	do				Do.
Panti-pangtanigi	do				Do.
Pantukos	do				Tuck seine.
Pantulingan	Batangas Tagalog				Ring net.
Pantunton	Aklan Bisaya			Handline	
Panubidsubid	Sebu Bisaya			Troll line	
Panukot	Tagalog	Hook			
Panudsod	do				Push net.
Panugpo	do		Fish shelter		
Panuyo	Bisaya	Spear			
Panyambo	Aklan Bisaya			Troll line	
Do	Banton Bisaya			do	
Parangli	Maranaw-Spanish			Longline	
Parangre	Bisaya-Spanish			do	
Paranhe	do			do	
Paranyaki	Pangasinan				Drift net.
Parayray	do		Fish corral		Drag seine.
Pareng	Iloko		Fish pot		
Do	Ibanag		do		
Parigdig	Pangasinan				Lift net.
Paril	Sebu Bisaya		Fish corral		
Parisak	Ibanag		Fish trap		Dip net.
Parispis	Iloko				Lift net.
Parisris	do				Drive-in-net.
Parukdok	Pangasinan			Pole and line.	
Parugmon	Banton Bisaya		Fish shelter		
Pasabal	Kapampangan		Fish corral		
Do	Tagalog		do		
Pasabal-laot	do		do		
Pasabal-tabi	do		do		
Pasabang	Iloko		Fish trap		
Pasabing	do		Fish corral		
Do	Pangasinan		do		
Pasabing-duble	Pangasinan-Spanish		do		
Pasabing-ordinaryo	do		do		
Pasabing-sa-balank	Pangasinan		do		
Pasabing-sa-malaga	do		do		
Pasabing-sensilyo	do		do		
Pasaki	Sebu Bisaya		do		
Pasaking	Ibanag		do		
Pasadsaran	Tagalog		do		
Pasagad	Sebu Bisaya		do		
Pasagka	Bikol		do		
Pasaging	Ibanag		do		
Pasalambang	Batangas Tagalog				Drag seine.
Pasalugki	Iloko		Barricade		
Pasalugi	do		do		
Pasbang	Pangasinan		Fish trap		
Pasbang-duble	Pangasinan-Spanish		do		
Pasbang-sensilyo	do		do		
Paserser	Iloko				Drive-in-net.
Pasgong	Sebu Bisaya		Fish trap		
Pasikaɽod	Iloko		Barricade		
Pasol	Sebu Bisaya			Handline	
Pasol-lambo	do			Troll line	
Pasol-palangri	do			Longline	
Pasol-pangutob	do			Handline	

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
Pasudsod	Iloko			Longline	
Pasugki	do		Barricade		
Pasurong	do		do		
Pasursor	do			Longline	
Patakiyob	Sebu Bisaya				Trap net.
Patalang	Bikol				Gill net.
Pataob	Tagalog		Fish trap		
Patapat	Pangasinan		Fish shelter		
Pataw	Sebu Bisaya			Line	
Pataya	Iloko		Barricade		
Pateng	do		Fish pot		
Patibok	Tagalog				Drive-in-net.
Patibog	do				Gill net.
Patibong	do		Fish trap		
Do	Banton-Bisaya		do		
Patigbi	Ilongo Bisaya				Drive-in-net.
Do	Sambal				Do.
Patubog	Tagalog		Fish trap		
Patukba	do			Pole and line.	
Patuktok	Iloko			do	
Patudan	Pangasinan			do	
Patulid	do		Barricade		
Patulid-kileb	do		do		
Patuloy	Bisaya				Gill net.
Patunkad	Samal			Handline	
Do	Taw Sug			do	
Paturaw	Pangasinan			Pole and line.	
Do	Iloko			do	
Paugmad	Bisaya		Fish corral		
Do	Maranaw		do		
Payakyak	Pangasinan		do		
Payaan	Aklan Bisaya		do		
Payaw	Sebu Bisaya		Fish shelter		
Penir	Pangasinan		Fish corral		
Pika	Iloko			Handline	
Pidpid	Bikol				Filter net.
Pilangre	Dabawenyo			Longline	
Pinalusad	Sebu Bisaya		Fish corral		
Piner	Pangasinan		do		
Do	Sambal		do		
Pingi	Iloko		Barricade		
Pinid	Batangas Tagalog				Trap net.
Pinit	Tagalog		Fish corral		
Pipis	do				Drive-in-net.
Pisga	Iloko	Spear or harpoon			
Do	Pangasinan	do			
Plaan	Aklan Bisaya		Fish corral		
Populitin	Pangasinan		do		
Puket	Iloko				Filter net.
Do	Pangasinan				Do.
Pukot	Pilipino				Drag seine.
Do	Sebu Bisaya				Gill net.
Do	Tsabakano				Scoop seine.
Do	Batangas Tagalog				Purse seine.
Pukot-alangan	Tagalog				Drag seine.

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
Pukot-anod	Sebu Bisaya				Drift net.
Pukot-asan	Kapampangan				Drag seine.
Pukot-bangsi	Sebu Bisaya				Purse seine.
Pukot-barimbaw	Tagalog				Drag seine.
Pukot-basnig	Sebu Bisaya				Bag net.
Pukot-binatoan	do				Round haul seine.
Pukot-kanduli	Tagalog				Tuck seine.
Pukot-kasig	Samal				Gill net.
Pukot-kayagkag	Sebu Bisaya				Do.
Pukot-dalag	Tagalog				Tuck seine.
Pukot-gilid	do				Do.
Pukot-lamba	Sebu Bisaya				Gill net.
Pukot-laot	Tagalog				Tuck seine.
Do	Batangas Tagalog				Do.
Pukot-libgaw	Sebu Bisaya				Drag seine.
Pukot-likom-likom	do				Drive-in-net.
Pukot-likos	do				Gill net.
Pukot-likos-bato	do				Reef seine.
Pukot-mamarungoy	do				Stop seine.
Pukot-mamangsi	do				Purse seine.
Pukot-mangsi	do				Do.
Pukot-mubgas	do				Gill net.
Pukot-padlas	do				Do.
Pukot-padumog	do				Do.
Pukot-pahubas	do				Filter net.
Pukot-pamalo	do				Gill net.
Pukot-pamalubalo–kayagkag.	do				Do.
Pukot-pamangsi	do				Purse seine.
Pukot-pamarungoy	do				Do.
Pukot-pamaubgas	do				Gill net.
Pukot-pamubgas	do				Do.
Pukot-pamulinaw	do				Drag seine.
Pukot-pamuraw	do				Round haul seine.
Pukot-panalawasig	do				Gill net.
Pukot-panamban	do				Round haul seine.
Pukot-pang-araw	Batangas Tagalog				Ring net.
Pukot-pang-awa	Sebu Bisaya				Gill net.
Pukot-pangdalag	Tagalog				Ring net.
Pukot-panggab-i	Batangas Tagalog				Purse seine.
Pukot-panggilid	do				Drag seine.
Pukot-panghagumaa	Sebu Bisaya				Do.
Pukot-panghaol-haol	do				Gill net.
Pukot-pangmiralya	Batangas Tagalog				Purse seine.
Pukot-panlamba	Sebu Bisaya				Drag seine.
Pukot-panulingan	Batangas Tagalog				Tuck seine.
Pukot-panumbok	Sebu Bisaya				Gill net.
Pukot-paro	Kapampangan				Filter net.
Pukot-pataan	Sebu Bisaya				Trap net.
Pukot-sa-mudgas	do				Gill net.
Pukot-taktak	do				Drag seine.
Pugad	Kapampangan		Fish shelter		
Pugad-dalag	Tagalog		do		
Pugad-pugad	do		do		
Punor	Sambal		Fish corral		

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
Punot	Bisaya		Fish corral		
Do	Kuyonon		do		
Punupon	Iloko		Fish shelter		
Puot	do		Barricade		
Do	Samar Bisaya				Gill net.
Pupok	Iloko		Fish shelter		
Do	Ibanag		do		
Pusil-pusil	Sebu Bisaya	Spear			
Putos	Bikol				Drag seine.
Do	Bisaya				Do.
R					
Ragunot	Samar Bisaya				Drive-in-net.
Rama	Iloko		Fish shelter		
Ramahe	do		do		
Rama tinarikan	do		do		
Rantaw	Maranaw				Gill net.
Raway	do			Longline	
Raya	Samar Bisaya				Cast net.
Rede	Tsabakano				Drag seine; scoop seine.
Rineppet	Iloko		Fish shelter		
Rugmon	Banton Bisaya		do		
S					
Sabay	Bikol		Fish corral		
Do	Sebu Bisaya				Drag seine.
Sabukol	Pangasinan				Cast net.
Sabor	Sebu Bisaya		Fish shelter		
Sakag	Tagalog				Push net.
Do	do				Skimming net.
Sakdit	Ivatan				Pull net.
Saklit	do				Push net.
Do	do				Drag seine.
Do	Kapampangan				Push net.
Saklitan	Tagalog		Fish corral		
Saksakaw	Iloko				Drag seine.
Saksaklang	do				Do.
Sakwal	Samar Bisaya				Tuck seine.
Sakwat	Tagalog				Push net.
Sakyaw	Sambal				Drift net.
Do	Iloko				Do.
Sakyod	Tagalog				Drag seine.
Sakyor	do				Do.
Sada	Bikol		Barricade; fish corral.		
Sadeng	Iloko				Gill net.
Do	Sambal				Do.
Sadeng-pamaramban	do				Do.
Sadeng-pammilis	do				Gill net.
Sagad	Sebu Bisaya				Scoop seine.
Do	Iloko	Rake			
Sagangat	Sebu Bisaya	Harpoon			
Sagap	Iloko				Drag net.
Do	do				Drive-in-net.
Do	Sambal				Push net.

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
Sagap	Batangas Tagalog				Drag seine.
Do.	Bisaya				Do.
Sagap-aramang	Iloko				Do.
Sagap-kon-pataray	do.				Drive-in-net.
Sagap-duron-duron	do.				Push net.
Sagap-dusdos	do.				Do.
Sagkad	Bikol		Fish corral.		
Sagiwsiw	Bisaya				Drive-in-net.
Sagop	Sebu Bisaya		Barricade.		
Sagudsod	Kapampangan	Scoop.			
Saguysoy	do.				Drive-in-net.
Sahakeb	Ivatan				Dip net.
Sahapang	Samal	Spear.			
Do.	Taw Sug	do.			
Sahid	Bisaya				Drag seine.
Do.	Bikol				Do.
Sahid-sahid	Sebu Bisaya				Skimming net.
Sahid-salibut	do.				Drift net.
Sahid-sinurambaw	do.				Drive-in-net.
Sahuran	Aklan Bisaya		Fish corral.		
Sain-sain	Sebu Bisaya				Round haul seine.
Sala	Tagalog				Filter net.
Salakab	do.	Cover pot.			
Do.	Bisaya	do.			
Salambaw	Tagalog				Lever net.
Do.	Pangasinan				Lift net.
Do.	Sambal				Do.
Do.	Bikol-Tagalog				Do.
Do.	Bisaya				Do.
Salambaw-basnig	Bikol				Bag net.
Salambaw-buton	Pangasinan				Lift net.
Salambaw-inalong	do.				Do.
Salambaw-parigdig	do.				Do.
Salanguwang	Iloko		Fish pot.		
Salap	Pilipino				Drag seine.
Do.	Tagalog				Dip net and skimming net.
Do.	Sambal				Lift net.
Do.	Batangas Tagalog				Push net.
Salapang	Bisaya	Spear.			
Do.	Tagalog	do.			
Salap-balaw	Bikol				Drag seine.
Salap-hipon	Tagalog				Do.
Salibot	Bisaya				Gill net.
Do.	Sebu Bisaya				Drag seine.
Do.	Tagalog-Bikol				Filter net.
Salilo	Aklan Bisaya		Fish corral.		
Salimpukot	Sebu Bisaya				Drag seine.
Saliwsiw	Bikol	Rake.			
Do.	Banton Bisaya				Drive-in-net.
Do.	Aklan Bisaya				Do.
Salok	Tagalog				Dip net.
Salubang	Kuyonon	Spear.			
Do.	Aklan Bisaya	do.			
Salungat	Subanon		Fish corral.		
Saluran	Bisaya		do.		

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
Salwag	Igorot				Cast net.
Salyang	Pangasinan				Crab lift net.
Salyang	Iloko		Fish pot		
Sampay	Maranaw				Tuck seine; gill net.
Sankal	Bikol				Push net.
Saneb	Iloko		Barricade		Cast net.
Sangab	Sebu Bisaya				Round haul seine.
Sangat	do		Fish corral		
Sapang	Samal	Spear			
Do	Taw Sug	do			
Sapang-kon-antipara	Sebu Bisaya	do			
Saplad	Pilipino				Filter net.
Do	Tagalog		Barricade		
Saplad-para-alamang	do				Filter net.
Saplar	Iloko				Do.
Do	Ibanag				Do.
Do	Pangasinan				Do.
Sapyar	Ibanag				Do.
Sapyaw	Pilipino				Round haul seine.
Do	Batangas Tagalog				Gill net.
Do	Bikol				Drive-in-net.
Do	Bikol and Bikol-Tagalog		Fish shelter		Skimming net.
Sapyaw-kon-luses	Bisaya-Spanish				Round haul seine.
Sapyaw-de-kuerdas	Samar Bisaya-Spanish				Do.
Sapyaw-lawag	Samar Bisaya				Do.
Sapyaw-lawagan	do				Do.
Sapyaw-ordinaryo	do				Do.
Sapyaw-sa-boya	Bikol-Spanish		Fish shelter		Skimming net.
Sapyaw-sa-gilid	Bikol				Dip net.
Sapyaw-sa-hapon	Sebu Bisaya				Japanese round haul seine.
Sara	Bikol-Spanish		Barricade		
Sarabay	Kuyonon				Push net.
Sarading	do		Fish trap		
Sarap	Bisaya				Drag seine.
Do	Bikol				Do.
Do	Kuyonon				Do.
Do	Iloko		Barricade		
Do	Sebu Bisaya				Trap net.
Sarap-banata	Bisaya				Drag seine.
Sarap-para-balat	Samar Bisaya				Do.
Sarap-para-hipon	do				Do.
Sarap-sa-balanak	Bikol				Drag seine.
Sarap-sa-balaw	do				Do.
Sarapang	do	Spear			
Sarawsaw	Ilongo Bisaya				Lift net.
Sarep	Iloko		Barricade		
Sariwsiw	Pangasinan				Drive-in-net.
Sasad	Iloko				Do.
Sawayan	Ilongo Bisaya				Drag net.
Sawsaw	Taw Sug				Dip net.
Do	Samal				Do.

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
Sayanggong	Iloko				Round haul seine.
Do	Ibanag				Do.
Sayanggong-sapyaw	Iloko				Do.
Sayap	Banton Bisaya				Drag seine.
Do	Aklan Bisaya				Do.
Saykit	Tagalog				Do.
Sayding	Iloko			Jigger	
Sayok	Ibanag				Lift net.
Sayod	Aklan Bisaya				Drag net.
Do	Iloko				Filter net.
Sayot	do				Lift net.
Sayring	Pangasinan				Trawl net.
Sayudsod	Iloko				Push net.
Sayursor	Sambal				Do.
Seket	Tagalog				Drive-in-net.
Sellem	Iloko				Crab lift net.
Do	Ibanag				Do.
Serada	Bisaya-Spanish		Barricade		
Sera-sera	Ilongo Bisaya Spanish		Fish corral		
Sibat	Tagalog	Spear			
Do	Bisaya	do			
Sibbing	Iloko		Barricade		
Sibid-sibid	Tagalog			Troll line	
Do	Bikol			do	
Do	Bisaya			do	
Sibot	Tagalog				Dip net.
Do	Aklan Bisaya				Do.
Do	Bisaya				Do.
Siklong	Pangasinan		Fish trap		
Sikpaw	Pilipino				Dip net.
Sikpaw-pamangsi	Sebu Bisaya				Do.
Sigay	Iloko				Gill net.
Do	Sambal				Do.
Sigay-palayupoy	Iloko				Drift net.
Sigay-sa-awa	do				Do.
Sigin	Pilipino				Scoop seine.
Sigpaw	Bisaya				Dip net.
Do	Bikol-Tagalog				Do.
Sihod	Sebu Bisaya	Scoop			Do.
Siid	Tagalog		Fish-pot-like trap.		
Do	Pangasinan		do		
Siir	Sambal		do		
Do	do			Pole and line.	
Siir-na-alalo	do			do	
Siir-na-paltat	do			do	
Silew	Pangasinan			do	
Silhig	Banton Bisaya		Fish trap		
Silo	Tagalog	Snare			
Do	Bikol				Dip net.
Silot	Pangasinan				Tuck seine.
Do	Iloko				Gill net.
Sima	Batangas Tagalog				Dip net.
Do	Tagalog	Cover pot.			
Sinapyaw	Ilongo Bisaya				Round haul seine.

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
Sindok	Samar Bisaya				Skimming net.
Sinipete	Tagalog Spanish		Fish corral		
Sinog-an	Sebu Bisaya		do.		
Sinsoro	Pilipino-Spanish				Drag seine.
Sinsoro-hapones	do.				Drive-in-net.
Sinsoro-panalikop	Batangas Tagalog-Spanish.				Purse seine.
Sinsoro-pangdayo	Batangas Tagalog				Drag seine.
Sinsoro-panggilid	do.				Do.
Sintak	Sebu Bisaya			Pole and line.	
Sintsoro	Sebu Bisaya-Spanish				Beach seine.
Sinudlay	Subanon		Fish corral		
Sipayot	Iloko				Dip net.
Sira	Ilongo Bisaya-Spanish		Fish corral		
Do	Aklan Bisaya-Spanish		do.		
Sisilo	Ivatan				Gill net.
Siwasiw	Pangasinan			Pole and line.	
Sodsod	Bisaya				Push net.
Solambaw	Samar Bisaya				Lift net.
Solero	Ilongo Bisaya		Fish corral		
Songkit	Sebu Bisaya	Spear			
Sowal	Samar Bisaya				Tuck seine.
Subid-subid	Sebu Bisaya			Troll line	
Sukob	Tagalog				Cover net.
Sukob-ayungin	do.				Do.
Sukob-kanduli	do.				Do.
Sukob-dalag	do.				Do.
Sukod	Kampampangan				Do.
Sudsod	Bisaya				Push net.
Sugabaw	Ilongo Bisaya		Fish corral		
Sulambaw	Samar Bisaya				Drive-in-net.
Sulambaw-sin-asta	do.				Lift net.
Sulong	Batangas Tagalog				Push net.
Sulyang	Tagalog		Fish pot		
Sunggapong	Iloko				Dip net.
Sungya	Bisaya	Scoop			
Surambaw	do.				Drive-in-net.
Do	Bikol				Do.
Surambaw-hapones	Bisaya-Spanish				Do.
Surambaw-paligid	Ilongo Bisaya				Do.
T					
Taan	Bikol		Barricade		
Do	Bisaya		do.		
Do	Sebu Bisaya			Longline	
Taba	Bisaya		Fish corral		
Tabak	Iloko				Drag seine.
Tabag	Ibanag				Do.
Tabal	Pangasinan				Gill net.
Do	do.				Drag seine.
Tabal-kon-bato	do.				Gill net.
Tabal-kon-paltaw	do.				Do.
Tabal-grande	Pangasinan-Spanish				Drag seine.
Tabal-pikinyo	do.				Do.
Tabar	Pangasinan				Drift net.
Taba-taba	Aklan Bisaya		Fish corral		

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
Tabon	Bisaya		Fish pot		
Tabukol	Iloko				Cast net.
Tabukol-areb	do				Do.
Tabukol-baybay	do				Do.
Tabukol-karayan	do				Do.
Tabukol-pamaltat	do				Do.
Tabukol-panaaw	do				Do.
Tabukol-panarayan	do				Do.
Tabukol-pang-ayungin	do				Do.
Tabukol-pangdalag	do				Do.
Takib	Tagalog				Filter net.
Takibo	do				Drag seine.
Takilis	do		Fish trap		
Do	do				Drive-in-net.
Takis	Ilongo Bisaya		Fish corral		
Takit	Iloko				Dip net.
Do	Ibanag				Do.
Taklob	Ilongo Bisaya	Cover pot			
Do	Sebu Bisaya				Cast net.
Tako	Iloko	Dredge			
Taksay	Pilipino				Trawl net.
Do	Aklan Bisaya				Drag seine.
Takwit	Ibanag				Dip net.
Takyaw	do				Round haul seine.
Taga	Sambal		Fish corral		
Do	Sebu Bisaya	Spear			
Tagaban	Iloko	Scoop			
Tagabang	do		Fish corral		
Do	Tagalog-Bikol		do		
Tagad	Ilongo Bisaya	Spade			
Tagara	Ibanag				Drag seine.
Tagata	Bisaya				Do.
Tagon	Ilongo Bisaya			Handline	
Tagulanglang	Sebu Bisaya				Drag seine.
Tain	Tagalog		Fish pot		
Taing	do		do		
Talabog	do		Fish-pot-like trap		
Talakeb	Pangasinan	Cover pot			
Talakob	Tagalog				Purse seine.
Talakop	do				Do.
Talakop-sa-gilid	do				Do.
Talapang-de-balat	Pangasinan-Spanish	Hook			
Talik	Magindanaw		Fish corral		
Tallakeb	Iloko	Cover pot			
Talunton	Bisaya			Handline	
Tamang	Ibanag				Drag seine.
Tamba	Sebu Bisaya				Trap net.
Tambak	Bikol		Barricade		
Do	Bisaya		Fish shelter		
Tambog	do				Gill net.
Tambon	Ilongo Bisaya		Fish shelter		
Tambong	Bikol		do		
Taming	Sebu Bisaya		Fish pot		
Tampuli	Samar Bisaya	Spear			
Tankob	Sebu Bisaya		Fish corral		
Tangab	Ilongo Bisaya				Filter net.
Tangkop	Bisaya		Fish corral		

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
Tanggar	Iloko				Filter net.
Tango	do				Tuck seine.
Taon	Aklan Bisaya		Fish pot		
Taon-kinaban	Bisaya		do		
Taon-ligid	do		do		
Tapangan	Tagalog		do		
Do	Pangasinan		do		
Do	Sambal		do		
Tapsay	Bisaya				Drive-in-net.
Do	Maranaw				Do.
Do	Iloko				Trawl net.
Do	Pangasinan				Do.
Tarangutong	Iloko		Fish shelter		
Tarapang	do	Spear			
Taraya	Moro				Cast net.
Do	Bisaya				Do.
Tarek	do		Fish corral		Filter net.
Do	Magindanaw		do		
Tarek	Sambal		do		
Tatasay	Iloko				Trawl net.
Tatasay-tirong	do				Do.
Taunton	Sebu Bisaya			Handline	
Taya	Iloko		Barricade		
Tayog	do				Lift net.
Teg	do				Dip net.
Do	Ibanag				Do.
Telalakal	Kapampangen		Fish trap		
Tellem	do				Crab lift net.
Tete	Samar Bisaya	Pick			
Tikpaw	Ilongo Bisaya				Dip net.
Tiksal	Tagalog	Spear			
Tigaanan	Aklan Bisaya			Pole and line.	
Tigbi	Ilongo Bisaya				Drive-in-net.
Tigpaw	Tagalog				Dip net.
Tigsal	do	Spear			
Tiid	Iloko				Drag seine.
Tilay	Tagalog			Handline	
Timing	Bisaya		Fish pot		
Tinagala	Maranaw		Fish corral		
Do	Bisaya		do		
Tinagalog	Sebu Bisaya		do		
Tinumpang	Samar Bisaya				Gill net.
Tinures-pahubas	do		Fish corral		
Tipsay	Sebu Bisaya				Drive-in-net.
Tirador	Kuyonon-Spanish	spear			
Trapang	Iloko	do			
Tsintsoro	Pilipino-Spanish				Drag seine.
Tuad	Iloko				Do.
Tubog	Batangas Tagalog			Handline	
Tued	Iloko				Drag seine.
Tuel	Pangasinan		Fish corral		
Tulbong	Samar Bisaya				Cast net.
Tulis	Bisaya		Fish corral		
Tulokutok	Palanan				Drive-in-net.
Tumbok	Sebu Bisaya				Gill net.
Tunda	Samal			Troll line	

Vernacular names	Dialects	Classification			
		Nontextile devices		Textile devices	
		Hand instruments	Barriers and traps	Lines	Nets
Tungaltaw	Iloko			Handline	
Do	do			Pole and line.	
Tungkob	Samal		Fish pot		
Tuwitang	do			Longline	
Tunton	Aklan Bisaya			Handline	
Tuyongan	Ivatan			do	
Tuyotuyan	do				Dip net.
U					
Udaod	Iloko				Lift net.
Ugmad	Samar Bisaya		Fish corral		
Ugnat	Tagalog				Drive-in-net.
Ulang-ulang	Sebu Bisaya			Squid jig	
Do	Samal			do	
Umang	Tagalog		Fish trap		
Unasan	Bisaya		Barricade		
Unay	do		Fish corral		
Do	Bikol		do		
Unosin	Ivatan			Troll line	
Utase	Pilipino-Hapones				Beam trawl.
W					
Wangayan	Sebu Bisaya		Fish corral		
Waswas	do		do		
Wisawisan	Iloko			Pole and line.	
Y					
Yako	Tagalog				Dredge net.
Yada	Banton Bisaya				Cast net.
Yagpit	Aklan Bisaya		Fish trap		
Yambo	do			Troll line	
Do	Banton Bisaya			do	
Yaya	Aklan Bisaya				Cast net.

Part V. GLOSSARY OF PHILIPPINE FISHING GEAR

A

abang (Tagalog).—A fish corral constructed near a river mouth. It is designed with two wings and two collecting pounds or cribs, but has no leader. It is larger than a bunuhan (Tag.), and therefore is set in much deeper water. *Synonyms:* Bunuhan (Tag.); tagabang (Ilk.; Tag.-Bik.); baklad-balango (Kap.).

aboy-bating (Bikol).—A tuck seine operated during the dark of the moon for catching silinyasi (small sardines). A cordon of small boats scares or drives the fish into the bag with the aid of light. *Synonyms:* Pantukos (Tag.); pangtrukos (Kab.).

agahid (Samar Bisaya).—A beach seine of either sinamay or cotton netting. *Synonyms:* Sinsoro (Pil.-Sp.); salap (Bis.; Bik.; Tag.).

agila (Tagalog-Spanish).—A shallow-water fish corral in Manila Bay. Placed in water about 3 or 4 fathoms deep, it is provided with a leader to a semicircular enclosure. The two opposite and tapering ends of the enclosure lead into two pounds. *Synonyms:* Agila-baybayin (Tag.-Sp.); baklad-panggilid (Tag.); angkla (Tag.-Sp.); baklad-gilid (Tag.).

agila-baybayin (Tagalog-Spanish).—A shallow-water fish corral constructed not far from shore in Navotas, Rizal Province, in Manila Bay. *Synonyms:* Agila (Tag.-Sp.); baklad-panggilid and baklad-gilid (Tag.); angkla (Tag.-Sp.); inangkla (Sam. Bis.).

agoyan (Iloko).—A barricade for catching gobies in rivers. It is made of weeds and leaves, with the collecting portion fashioned of a blanketlike cotton net. This gear is operated with a scareline. *Synonym:* Aguyan (Ilk.).

aguyan (Iloko).—A combination barricade and drive-in-net for catching ipon (young gobies) in rivers of northern Luzon. *Synonym:* Agoyan (Ilk.).

alang (Pangasinan).—A lever net similar to the salambaw (Tag.) which consists of a large dip net attached to two bamboo cross pieces. It is lowered and raised by a leverlike boom stepped to a bamboo raft.

alas-na-kupas (Bikol-Spanish).—A shallow-water fish corral set in about 7 feet of water in San Miguel Bay for catching shrimp. The name is derived from its ground plan, which resembles the shape of the ace of hearts of the Spanish playing card. *Synonyms:* Pamasayan (Bik.); natural and ordinaryo (Bik.-Sp.).

alkabos (Tagalog-Spanish; Kapampangan-Spanish).—A fish spear or harpoon used in catching dalag as the fish appear at the surface to breathe. Energy is furnished by a bowlike device mounted on a wooden stock. A three-pronged shaft, with either detachable or non-detachable blades, is fitted into a groove on the upper surface of the stock. *Synonym:* Arkabus (Tag.-Sp.).

ale (Sebu Bisaya).—A gill net hung like a curtain from the outriggers of a lighted boat to catch slightly stunned (poisoned) fish. It is generally made of cotton twine knitted with a mesh of ¾-inch, stretched.

amba (Ilongo Bisaya).—A barricade constructed in rivers and brooks for catching mullet and other fish migrating downstream. It is made of split-bamboo matting and stones and has an inclined landing platform of split bamboo.

ambak (Bikol).—A movable fish corral with two long wings and a collecting pound. The fish are caught during receding tide. *Synonyms:* Sabay (Bik.); pahubas (Bis.); pahibas (Tag.).

ambulante (Tagalog-Spanish).—A fish corral with a fish pot as the collecting device, instead of the conventional collecting crib or pound, which fishes during receding tide. *Synonyms:* Pahubas (Bis.); sabay (Bik.); pahibas (Tag.).

ampas (Bisaya).—A fish corral consisting of two wings without a leader. A bubo (fish pot) or a pukot (seine) forms the collecting portion. Capture of fish is effected during receding tide.

ampis (Bisaya).—A filter net of sinamay (abaka cloth) for catching small shrimp in very shallow tidal waters. When used at sea from a banca, it becomes a tuck seine for catching alamang (small shrimp).

angkla (Tagalog-Spanish).—A shallow-water fish corral similar to the agila (Tag.-Sp.).

anod (Bisaya).—Drift nets in general, for catching different kinds of fish.

anod-pamili (Maranaw).—A drift net used in Lake Lanao for catching mullet.

anod-pangawa (Sebu Bisaya).—A drift net used in catching awa (spawning bangos).

ansad (Bikol).—A river fish corral for catching eels. It has a landing platform and is constructed across the streams.

ansag (Sambal).—A barricade with a bamboo landing platform which is used in rivers for catching small fish, especially gobies. *Synonym:* Asar (Ilk.).

ansag (Bikol).—A fish corral similar to the palukso (Tag.), which is provided with a landing platform where the catch is collected. *Synonym:* Ansad (Bik.).

antol (Sebu Bisaya).—A barricade of stones used in coral reef fishing. The fish are caught after they have been stranded in the enclosed space during the receding tide.

aplos (Sebu Bisaya).—A drive-in-net used with a scareline.

aranas (Bisaya-Spanish).—A jig with one or more series of barbless hooks at one end for catching squids. The gear is jerked occasionally while being towed by a banca. *Synonym:* Aranyas (Bis.-Sp.).

aranyas (Bisaya-Spanish).—A squid jig. *Synonym:* Aranas (Bis.-Sp.).

arkabos (Tagalog Spanish; Kapampangan-Spanish).—A spear or harpoon. *Synonym:* Alkabos (Tag.-Sp.).

arikos (Samar Bisaya).—An encircling gill net for catching mullet.

arikos-sa-bato (Samar Bisaya).—An encircling gill net for catching fish in coral reefs.

arong (Samar Bisaya).—A fish shelter composed of a pile of twigs, bushes, branches of trees, etc., held in place by bamboo poles stuck into the ground. After impounding the fish and clearing the spot of debris, the catch is collected by various means. *Synonyms:* Bumbon (Tag.); rama or ramahe (Ilk.); lama (Pang.).

arpon (Sebu Bisaya Spanish).—A fish harpoon used in Cebu Province for catching large fish such as rays, sharks, and sometimes whales. It is operated by manpower.

asad (Iloko).—A cover pot used to cover fish, especially dalag. It consists of a cylindrical device made of bamboo splints and has no nonreturn valve. Also, it has a wide lower opening and a much smaller upper opening, and the catch is retrieved by hand through the latter. *Synonym:* Salakab (Tag.).

asar (Iloko).—A barricade constructed of mud and gravel across rivers in northern Luzon for catching small fish, especially gobies, on their downstream migration. The collecting device at the center of the gate has a platform of woven bamboo with a dam of banana stalks above it, and an enclosure below where the fish are caught. It differs from the patulid (Ilk.) in the type and location of the collecting device employed.

asog (Ilongo Bisaya).—A type of fish corral used in Panay Island. *Synonyms:* Baklad (Tag.); bunuan (Sam. Bis.); sagkad (Bik.); pasabing (Ilk.).

ataraya (Tsabakano; Sebu Bisaya-Spanish).—An adapted Spanish term for cast nets of various sizes and specifications. *Synonyms:* Dala (Tag.); laya (Bis.); tabukol (Ilk.); lala (Samb.); sabukol (Pang.); esparabel (Bis.-Sp.; Iban-Sp.).

ataraya-panamban (Sebu Bisaya-Spanish).—A cast net for catching tamban (sardines; *Sardinella longiceps* and *Sardinella sirm*).

ataraya-pangguno (Sebu Bisaya-Spanish).—A cast net for catching guno (silversides).

atob (Ilongo Bisaya).—A barricade of stones used in coral reef fishing. *Synonyms:* Atog (Il. Bis.); antol (Seb. Bis.).

atog (Ilongo Bisaya).—A barricade of stones used in coral reef fishing. *Synonyms:* Antol (Seb. Bis.); atob (Il. Bis.).

atol (Kuyonon).—A fish corral of one or two chambers, made of split bamboo matting, which is from 6 to 9 feet deep. The outside is reinforced with piles of rocks.

B

babaw-on (Ilongo Bisaya).—A term for fish pots in Libacao, Capiz Province. *Synonym:* Taon (Bis.).

babhas (Sebu Bisaya).—A shallow-water fish corral which filters the catch during receding tide. *Synonym:* Pahubas and pabhas (Bis.).

bakikong (Tagalog).—A small, heart-shaped, potlike trap for catching hito (clariid catfish). Strong smelling bait is used to attract the fish. The gear is made of split bamboo matting, 3- by 1½-feet, and has a nonreturn device. *Synonyms:* Siid, umang, and dakikong (Tag.); tarik (Ilk.).

baklad (Tagalog; Sambal; Kapampangan).—A set trap or corral of bamboo mattings or chicken wire arranged to form chambers. It has two wings generally with, but sometimes without, a long leader. It is designed as a guiding barrier with an intricate system of successive enclosures, which make entrance easy, but exit difficult. *Synonyms:* Bunuan (Sam. Bis.); sagkad (Bik.); pasabing (Ilk.); punot (Il. Bis.); bungsod (Seb. Bis.); bunsol (Sa.).

baklad-alangan (Tagalog).—A fish corral in Laguna de Bay which is set in the middle depths between the deep fish corrals and the very shallow ones.

baklad-bakuod (Batangas Tagalog).—A type of fish corral of the pangalato type having angular chambers. It was introduced into Balayan Bay by the Cavite fishermen. *Synonym:* Panggalato (Sam. Bis.; Bik.).

baklad-balango (Kapampangan).—A river fish corral with two wings and collecting cribs, but without a leader. *Synonyms:* Bunuhan (Tag.); abang (Tag.).

baklad-bukana (Batangas Tagalog).—A fish corral constructed near mouths of rivers in Batangas Province.

baklad-gayarin (Tagalog).—A fish corral in Manila Bay constructed in 9-fathom depth.

baklad-gilid (Tagalog).—A shallow-water fish corral in Manila Bay constructed about 50 yards from shore. In Laguna de Bay, the term refers to a corral with only one collecting pound. *Synonym:* Agila-baybayin (Tag.-Sp.).

baklad-laot (Tagalog).—A deep-water fish corral. In Laguna de Bay it is constructed in depths of 2 to 3 fathoms, and in Manila Bay, 3 to 9 fathoms.

baklad-madalang (Tagalog).—A fish corral in Bataan Province for catching larger species such as snappers, groupers, porgies, and cavallas. It is made with widely-spaced matting.

baklad-malamba (Tagalog).—A deep-water fish corral similar to baklad-laot (Tag.).

baklad-malimit (Tagalog).—A fish corral operated in Bataan Province for catching small fish such as anchovies and sardines. Narrowly-spaced mattings are used.

baklad-paktang (Tagalog).—A fish corral used in Bataan Province.

baklad-paglibis (Kapampangan).—A shallow-water fish corral of the agila type. *Synonym:* Agila-baybayin (Tag.).

baklad-palapad (Tagalog).—A fish corral made to fish during the ebbing tide as the fish migrate back to the deeper waters. It is constructed with two long wings and a collecting crib, and during high tide it is set parallel, or almost parallel, to the coastline.

baklad-pandak (Batangas Tagalog).—A shallow-water fish corral used in Batangas and Balayan Bays for catching species of fish that travel in schools.

baklad-pangbukana (Batangas Tagalog).—A fish corral constructed in Lake Taal near the mouth of its outlet into the Pansipit River.

baklad-panggilid (Tagalog).—A shallow-water fish corral constructed near the shore in Manila Bay. *Synonym:* Baklad-gilid (Tag.).

baklad-pang-ilog (Batangas Tagalog).—A fish corral constructed in rivers, especially in the Pansipit River, for catching migratory fish.

baklad-pangmalalim (Batangas Tagalog).—A deep-water fish corral in Balayan and Batangas Bays for catching tuna, mackerel, and other large pelagic species. The leader is not necessarily constructed toward the shore as is normally done, but is set so as to intercept the natural movement of these species in a particular locality.

baklad-pangwawa (Batangas Tagalog).—A fish corral constructed in Balayan and Batangas Bays near mouths of rivers for catching migratory fish.

baklad-pansipit (Batangas Tagalog).—A fish corral in the Pansipit River which catches fish from Lake Taal by intercepting them on their seaward migration. It is designed with two wings and a series of collecting chambers leading into a live-box brailing crib. The gear has no leader.

baklad-salukan (Tagalog).—A fish corral constructed in deeper water near Bataan in Manila Bay. It is provided with a collecting pound or crib from which the catch is brailed by dip nets.

baklad-salukil (Kapampangan).—Kapampangan or Pampango term for fish corrals in Manila Bay from which the catch is collected by dip nets. *Synonyms:* Baklad-salukin (Tag.); baklad-salukan (Tag.).

baklad-salukin (Tagalog).—A Bataan term for baklad-salukan.

baklad-siid (Tagalog).—A small shallow-water fish corral in Laguna de Bay similar to baklad-gilid (Tag.).

baklad-wawa (Batangas Tagalog).—A fish corral constructed near river mouths in Batangas Province. *Synonym:* Baklad-pangwawa (Bat. Tag.)

baklar (Banton Bisaya).—A general term for fish corrals among the Visayans in Odiongan, Tablas Island; Simara Island; Maestro de Campo and Banton Islands, Romblon Province. *Synonyms:* Baklad (Tag.); bunuan (Sam. Bis.); sagkad (Bik.); pasabing (Ilk.); bungsod (Seb. Bis.); bunsol (Sa.).

bakod (Ilongo Bisaya).—A fish corral in Negros Occidental Province.

bakusad (Ilongo Bisaya).—A river fish-corral consisting of two diverging wings of split bamboo matting supported by wooden posts. The collecting pound, 2 by 2 feet, is a somewhat square chamber and serves as a live-box.

bakutot (Tagalog).—A triangular floating potlike trap used in Mindoro Province. This trap measures 12 to 15 feet at base and top, and 18 feet in height. Its walls and floor are of bamboo matting, and it has a non-return valve. A bamboo raft, which is anchored by rattan lines tied to a big rock, keeps the trap afloat. *Synonym:* Bukatot (Tayabas Tag.).

badlas (Sebu Bisaya).—A set gill net baited with crushed or ground shrimp. *Synonym:* Padlas (Sam. Bis.).

bahan (Bisaya).—A drive-in-net used for coral reef species. It is made of sinamay and is operated with a scareline. *Synonyms:* Kayakas (Tag.; Pang.); baling-lukay (Bis.); lukayan and pukot-likom-likom (Seb. Bis.).

bahan (Samar Bisaya).—A fish trap of split bamboo matting used in Kankabatok Bay, Leyte Province. It is operated with a scareline of coconut leaves.

bahan (Bikol).—A drive-in-net for catching coral reef species. Made of sinamay, it is mounted on a triangular bamboo frame and is fished with a long scareline of coconut leaves.

bahid (Bikol).—A drag or beach seine made of cotton netting.

balahan (Bisaya).—A Sebu and Ilongo Bisaya term for a drive-in-net with a scareline of coconut leaves. *Synonym:* Bahan (Sam. Bis.).

balahan-mora (Sebu Bisaya).—A balahan or drive-in-net with a scareline introduced by the Moros into Negros Oriental Province.

balahan-pamalo (Sebu Bisaya).—A drive-in-net with scareline for catching balo (garfish) in Negros Oriental Province.

balasnig (Samar Bisaya).—A bag net used for catching surface fish traveling in schools. It is made of either cotton netting or sinamay and is operated during the dark of the moon with the aid of light from sailing bancas. *Synonym:* Basnig (Pil.).

balayan (Sebu Bisaya).—A deep-water fish corral from which the catch is brailed out with a bag net (basnig-like net).

balaybay (Ilongo Bisaya).—A type of fish corral used in Balete, Capiz Province.

balerong (Sebu Bisaya).—A type of fish corral used in Cebu and Zamboanga Provinces. Sometimes the term refers to a live-box.

balhin-balhin (Sebu Bisaya).—A Bohol-Bisaya term for movable fish corrals. *Synonyms:* Pahubas (Bis.); balhinon (Seb. Bis.).

balhinon (Sebu Bisaya).—A movable fish corral. *Synonym:* balhinbalhin (Seb. Bis.).

baling (Bisaya).—A general Bisaya term for sinamay drag or beach seines, made with or without bags. *Synonyms:* Baring (Sam. Bis.); pukot (Tag.; Bis.); salap (Bis.); daklis (Ilk.).

balingad-ngad (Tagalog).—A fish corral for taking dalag in Talavera, Nueva Ecija. Built in inland bodies of water, it is designed with two wings, a heart-shaped enclosure, landing platform, and live-box. *Synonym:* Palukso (Tag.).

balingato (Iloko; Ibanag).—A hoop net.

baling-baling (Sebu Bisaya).—A small drag seine made of sinamay.

baling-baling binidbiran (Sebu Bisaya).—A small drag seine of sinamay used in Bohol Province by the fishermen of Biliran Island, Leyte Province.

baling-kasaw (Sebu Bisaya).—A drag or beach seine used in Medellin, Cebu Province.

baling-lawod (Sebu Bisaya).—A tuck seine used in Cebu and Bohol Provinces. *Synonym:* Baling-sa-laod (Seb. Bis.).

baling-lukay (Sebu Bisaya).—A drive-in-net used with a scareline for catching coral reef fish. *Synonyms:* Kayakas (Tag.); bahan (Bis.).

baling-pangbaro-baro (Sebu Bisaya).—A drive-in-net with scareline used in Pilar, Cebu Province, for catching baro-baro (damsel fish).

baling-sa-laod (Sebu Bisaya).—A tuck seine. *Synonym:* Baling-lawod (Seb. Bis.).

baling-sinsoro (Sebu Bisaya).—A drag or beach seine used in Agusan Province.

balirong (Sebu Bisaya).—Either a fish corral or a live-box. *Synonym:* Balerong (Seb. Bis.).

balisasa (Kapampangan).—A large, cone-shaped fish pot for catching dalag and shrimp. About 30 feet long and made of split bamboo, it is set against the current in rivers.

baliwasnan (Batangas Tagalog).—A pole and line used in still fishing along banks of rivers and wharves. *Synonyms:* Binwit (Tag.); biwas (Tag.).

baliwit (Pangasinan; Sambal).—A term for handlines.

balsa (Bisaya-Spanish).—A fish shelter built in the form of a bamboo raft for attracting small fish. These act as bait for larger fish, which are caught in bubos (fish pots) lying on the bottom beneath the shelter.

balumbong (Tagalog).—A fish trap used in Lake Sampaloc for catching dalag and goby. It consists of three one-joint bamboo tubes tied together. Each tube has a hole just above the lower end node, and a retrieving line is attached to the upper node of one tube. The catch is made by intermittently hauling the trap and using a dip net to catch the fish that have entered the tubes through the holes.

baluyboy (Iloko).—A fish corral used in Bangar, La Union Province.

banata (Samar Bisaya).—An encircling gill net used for catching mararapad (gizzard shad).

banata (Tsabakano).—A small fish corral in Zamboanga Province which is designed with two wings and a collecting pound and is built at the gates of fish ponds.

banata-pukot (Samar Bisaya).—An encircling gill net for catching hardtails. It is made with a mesh of 2 inches, stretched, and is operated from one or two boats.

banatas (Sebu Bisaya).—A small drag seine used in northern Mindanao for catch-small shrimp and bangos fry. It is made of sinamay and measures 10 to 20 feet by 6 to 10 feet. *Synonym:* Sarap-banata (Seb. Bis.).

banate (Ilongo Bisaya).—A fish corral used in Occidental Negros Province.

ban-ay (Ibanag).—Cast nets. *Synonyms:* Dala (Tag.); laya (Bis.); tabukol (Ilk.); sabukol (Pang.); ataraya (Sa.); lala (Samb.); esparabel (Bis.-Sp.; Iban.-Sp.).

bangkulong (Kapamangan).—A fish shelter for taking dalag. It is made of bunches of twigs and other debris tied together and anchored or set in inland bodies of water. Fish are impounded by various textile or nontextile devices. In some places in Pampanga this term refers to pits dug along river banks. Entrances to these have wooden trap doors controlled by triggerlike devices. Dalag entering the trap hit the trigger and thereby close the door. Recently this term also has been used to designate a nestlike contraption for catching dalag. This consists of a floored and roofed nest of water hyacinths, 3 feet in diameter, with a side entrance. As the left hand closes the opening, the top of the trap is covered with a framed net, into which the scared fish jump. *Synonyms:* Bumbon (Tag.); pugad-pugad (Tag.); pugad-dalag (Tag.); rama (Ilk.); pugad (Kap.).

bangon (Batangas Tagalog).—A cylindrical fish pot used in Batangas Province for catching fresh-water shrimp and eels. It is employed as a collecting device in barricade fish shelters made of sand, mud, stones, and debris. Ground roasted maize is used for bait.

banhit (Sebu Bisaya).—A handline used in Argao, Cebu Province.

baniit (Iloko).—A handline used in small scale still fishing. The term also applies to a long pole and line used in fresh-water fishing. In Ilocos Norte Province, it denotes a multiple handline with from five to nine snooded hooks tied to a mainline, sunk by a conelike weight.

banit (Sambal).—A pole and line. *Synonym:* Binwit or biwas (Tag.).

banowit (Pangasinan).—General term for lines.

bantak (Bisaya).—A small, conelike or somewhat cylindrical, baited fish pot submerged in rivers, fishponds, and lakes for catching crabs and shrimp. Made of finely woven bamboo splints, it has a nonreturn valve at the wide opening. The smaller end tapers to a blunt apex which has a plugged opening through which the catch is removed. A floating retrieving line is attached by means of two rings.

bantak (Iloko).—A deep-sea handline used in commercial fishing. It is provided with two snooded hooks and a sinker and catches large fish. In Ilocos Norte Province the term also refers to a set pole and line, in which the pole is stuck along the river bank with live-frog bait for taking dalag. *Synonym:* Paadag (Ilk.).

bantak (Pangasinan).—A longline. *Synonym:* Kitang (Tag.).

bantak-igid (Iloko).—A baited hook attached to a short pole that is set in shallow water in rivers and left to fish unattended for a certain interval before being hauled in. *Synonym:* Paadag (Ilk.).

bantak-taaw (Iloko).—A handline for still fishing in the open sea with the aid of light. *Synonym:* Bantak (Ilk.).

banwar (Iloko).—A cotton filter net for catching shrimp. It is operated in mouths of rivers from a drifting boat.

banwar-rinakitan (Iloko).—A drifting filter net for taking shrimp. Made of sinamay, it is operated from a rakit (raft).

banwit (Bikol; Pangasinan).—A term for handlines.

banwit-pang-abo (Bikol).—A handline for catching abo (croaker) in San Miguel Bay, Camarines Sur Province.

barekbek (Iloko).—A small fish pot for catching udang (fresh-water shrimp), gobies, eels, etc. It is fished with broiled darak (rice bran) or corn husk baits. *Synonym:* Bubo (Ilk.).

barimbaw (Tagalog).—A shallow-water drag seine used in Laguna de Bay for taking dalag. Operated by four or five men, it is 100 to 150 fathoms long, carries floats on the corkline, but has no sinkers on the groundline. The catch is concentrated in a cotton netting bag supported by stakes, and brailed by dip nets. *Synonyms:* Pukot-dalag and pukot-gilid (Tag.).

baring (Samar Bisaya).—A drag or beach seine of varied construction. *Synonyms:* Baling (Bis.); pukot (Tag.; Bis.); salap (Bis.); daklis (Ilk.).

baring (Ibanag).—A drift net used in Cagayan Province with or without sinkers. *Synonyms:* Sigay or sakyaw (Ilk.); kitig (Kap.).

baring-baring (Samar Bisaya).—A small baring or drag seine of sinamay.

baslay (Ilongo Bisaya).—A spear gun with the arrowlike iron blade released by a trigger. Energy is furnished by a stretched piece of elastic, bow-and-arrow fashion.

baslig (Tagalog).—A bag net operated from a boat with the use of light. *Synonym:* Basnig (Tag.; Bis.).

basnig (Pilipino).—Originally, a Bisaya term for a conical or box-like bag net of sinamay or cotton webbing, which is operated from an outriggered sailing vessel as a huge dip net. It is used at night and fished with the aid of light. Basnig now generally refers to this type of net in many Filipino dialects, and powered vessels have been developed for handling it. The net is hauled from the tips of six guyed bamboo booms, each provided with a block. *Synonyms:* Balasnig (Sam. Bis.); baslig (Tag.).

basnig (Sebu Bisaya).—Bisaya term used in northern Mindanao to designate the round haul seine for sardines, anchovies, and other floating species which run in compact schools and can be attracted by light during the dark of the moon. *Synonyms:* Sapyaw (Tag.); iwag or lawag (Bis.); kabyaw (Bik.); sain-sain (Seb. Bis.).

basnig-likos-hapones (Ilongo Bisaya).—A term in Negros Bisaya which refers to the muro-ami (Japanese drive-in-net).

basnig-sululan (Ilongo Bisaya).—A lift bag net of sinamay operated with the aid of a torch during dark nights. It represents the primitive beginnings of the basnig (Pil.). *Synonym:* Basnig (Pil.).

basnig-tamban (Ilongo Bisaya).—A basnig (bag net) used for catching Indian sardines (tamban; *Sardinella longiceps*).

basursor (Iloko).—A longline used in Bauan, La Union Province. *Synonyms:* Pasursor (Ilk.); kitang (Tag.); darilay (Iban.).

batbating (Iloko).—A small triangular push net used for catching gobies and udang (shrimp), especially after a storm. Made of either sinamay or cotton, the net is pushed against the current in wading depths of rivers.

batkwas (Iloko).—A handline used in Paniqui, Tarlac Province.

batikong (Iloko).—A barricade used in northern Luzon rivers for catching ipon (goby fry). *Synonym:* Batikungkong (Ilk.).

batikungkong (Iloko).—A barricade used in northern Luzon rivers for catching ipon (goby fry). *Synonym:* Batikong (Ilk.).

bating (Tagalog).—An encircling gill net for taking sardines. Usually it is made of No. 40/4 cotton twine knitted with 1-inch mesh, stretched. It measures 4,000 meshes wide by 20 fathoms deep. The meshes run horizontally to the cork and leadlines. Fish are scared into the net by beating the water with wooden plungers. *Synonym:* Halang (Tag.).

batok (Iloko).—A small seine operated like a dip net by one man in catching gobies. The fisherman dives with it, sets the lower edge on the ground, and scratches the surroundings with his feet, scooping up sand, gravel, and fish. The fish are strained after being brought to the surface. This is a small version of the batbating (Ilk.), which is used in deep waters.

bayaba (Sebu Bisaya).—A fish corral in Agusan Province.

bayakos (Kapampangan).—A filter net used in rivers for catching shrimp. *Synonyms:* Diyakos or dayakos (Tag.).

bayakos (Batangas Tagalog).—A general term in Batangas and Mindoro Provinces for drag seines made of sinamay. *Synonyms:* Pukot (Tag.); baling (Bis.); baring (Sam. Bis.).

bayakos-pangbanka (Batangas Tagalog).—Large drag seines used in Batangas, which are usually made with a sinamay bag and operated from a banca. *Synonyms:* Sinsoro (Tag.-Sp.); pukot (Tag.; Bis.); tsintsoro (Pil.-Sp.).

bayakos-panggilid (Batangas Tagalog).—A shallow-water drag seine for coastal waters.

bayakos-panlakad (Batangas Tagalog).—A shallow-water drag seine operated by two men at wading depths.

bayot (Iloko).—A corrupted name for sayot (Ilk.), a type of push net used in northern Luzon for catching ipon (young gobies). Measuring 3 by 6 feet, it is mounted on a triangular bamboo frame.

bentoy (Banton Bisaya).—A crab lift net. *Synonyms:* Bintol (Pil.); sellem (Ilk.; Iban.); salyang (Pang.).

bentoyl (Aklan Bisaya).—A small, shallow, square, crab lift net. It is made of coarse mesh and mounted on two bamboo cross pieces. *Synonyms:* Bintol (Pil.); sellem (Ilk.; Iban.); salyang (Pang.).

besig (Sebu Bisaya).—A river barricade used in northern Mindanao for catching mullets migrating seaward. It is made with two wings of staked bamboo matting flanking an inclined bamboo platform at the center.

better (Iloko).—A barricade for catching ipon (goby fry) and other fish. It is operated with fish pots which are set several yards apart. Specifically, the term refers to barricades (dykes) made of banana stalks. *Synonym:* Etter (Ilk.).

bibedol (Samar Bisaya).—A fish spear operated with a bowlike device and used by fishermen divers. *Synonym:* Lilep (Sam. Bis.).

bikatot (Tagalog).—A small, somewhat cylindrical fish pot of flexible rattan used in Morong, Rizal Province, for catching dalag. *Synonym:* Bukatot (Tag.).

bidyo (Sebu Bisaya).—A bow-and-arrow type of fish spear in Negros Oriental Province and northern Mindanao, usually fished with the aid of light. *Synonym:* Bigyo (Seb. Bis.).

bigyo (Sebu Bisaya).—A fish spear used in Bohol Province. *Synonym:* Bidyo (Seb. Bis.).

binalinduko (Samar Bisaya).—A type of fish corral in Calbiga, Samar Province.

binaterol (Sebu Bisaya).—A medium-sized fish corral used in Zamboanguita, Negros Oriental Province, built in 1 to 3 fathoms of water.

bingit (Samal; Taw Sug).—Handlines used in the Sulu Archipelago.

bingwit (Maranaw).—Pole and line.

bintol (Pilipino).—A small, shallow, square, baited lift net for catching crabs. It is made of wide-meshed cotton netting mounted on bamboo crosspieces. The term also refers to a larger unbaited lift net of sinamay used in Cavite Province for catching shrimp. *Synonyms:* Sellem (Ilk.; Iban.); bentoy (Ban. Bis.); salyang (Pang.).

binwit (Tagalog).—General term for pole and line. *Synonyms:* Biwas (Tag.); baliwasnan (Bat. Tag.).

biray (Iloko).—A large drag or beach seine operated from a banca on the gradually shelving, smooth shores of northern Luzon. Made of cotton netting, usually with a bag or pocket, this seine is 300 to 750 by 8 fathoms. In the hauling process it is pulled to shore. It is larger than the daklis (Ilk.). *Synonyms:* Sinsoro (Pil.-Sp.); pukot (Pil.).

biray-kon-daklis (Iloko).—A large beach seine provided with a pocket. The term actually denotes a boat (biray) with a beach or drag seine (daklis). *Synonym:* Biray (Ilk.).

bisig (Bisaya).—A river barricade used in northern Mindanao for taking seaward-migrating fish such as mullet. It has an inclined landing platform at the collecting portion. In Samar this term is used to designate a fish corral of the bunuhan (Tag.) type constructed in rivers. *Synonym:* Paluksohan (Seb. Bis.).

bitana (Bikol; Bisaya).—A small drag or beach seine of sinamay or cotton netting made with or without a bag. *Synonyms:* Baring (Sam. Bis.); baling (Bis.); salap (Bis.).

bitay (Ilongo Bisaya).—A set pole and line. The bamboo pole is stuck into the river bank and requires only periodical attention.

bithay (Batangas Tagalog).—A small fish scoop used in the shallow water of the Pansipit River, Batangas Province, for collecting mussels. It is made of webbed bamboo splints on a circular frame and has no handle.

bitinan (Tagalog).—A dip net.

biwas (Tagalog).—Pole and line. *Synonyms:* Baliwasnan (Bat. Tag.); binwit (Tag.).

biyakos (Kapampangan).—A filter net made of cotton netting. *Synonyms:* Bayakos (Kap.); diyakos or dayakos (Tag.).

biyakos (Tagalog).—A small drag seine for catching shrimp. Made of sinamay, it is operated in rivers by two men. *Synonyms:* Saykit (Tag.); bayakos (Bat. Tag.).

biyakos-agila (Kapampangan).—A set filter net used for catching shrimp along the shores of Manila Bay near Pampanga Province. It is made in the form of a V-shaped trap with wings of staked, split bamboo matting. A sinamay bag filters the shrimp as the tide recedes.

biyakos-alamang (Kapampangan).—Similar to the biyakos-agila (Kap.), this filter net is set in rivers and takes the shrimp during their downstream migration.

biyakos-alimit (Kapampangan).—A small fish corral built along river banks or fish ponds chiefly for taking shrimp. It has two wings and a collecting crib from which the shrimp are brailed out by dip nets.

biyakos-bolusok (Kapampangan).—A river bank fish corral of split bamboo matting that fishes with the receding water. *Synonym:* Biyakos-palapad (Kap.)

biyakos-labitan (Kapampangan).—A series of three or four staked sinamay filter nets set near river mouths and made to fish chiefly for shrimp during flood tide.

biyakos-palapad (Kapampangan).—A fish corral built parallel to river banks that catches fish left behind when the river water recedes. *Synonym:* Biyakos-bolusok (Kap.).

biyakos-paro (Kapampangan).—Similar to but larger than the biyakos-labitan, these nets are sunk in 1 fathom of water and filter shrimp in their downstream migration.

biyaw (Sebu Bisaya).—A dip net used in Bohol Province.

bokatot (Iloko).—This is either a hoop net or a cylindrical bamboo fish pot set in creeks, paddy fields, or ditches with the opening facing the current to catch dalag and hito.

boholano (Tagalog).—A fish corral found in Peris Bay, Ragay Gulf. Its korona (semicircular enclosure) is a five-angled chamber, the three outer angles of which lead into three separate two-chambered cribs. This gear has a leader and two wings which are somewhat detached from the main structure.

bolitse (Bikol).—A drag or beach seine. *Synonym:* Sinsoro (Pil.-Sp.).

bombon (Pilipino).—A general term for fish shelters made of twigs, grasses, water hyacinths, etc., which lure fish seeking food and cover. The catch is made by hand or by various impounding or brailing devices. *Synonyms:* Bumbon (Tag.); rama or ramahe (Ilk.); lama (Pang.).

bonuan (Bisaya).—A general term in many Filipino dialects, especially Bisaya and Bikol, for various types of marine fish corrals. *Synonyms:* Baklad (Tag.); sagkad (Bik.); pasabing (Ilk.); punot (Il. Bis.); bungsod (Seb. Bis.); bunsol (Sa.); bunuan (Sam. Bis.).

bonuan-ordinaryo (Samar Bisaya).—A shallow-water fish corral built with a leader perpendicular to the shore. It has two short wings and two large connecting heart-shaped enclosures which lead into a small but deep collecting crib from which the catch is removed periodically with dip nets.

bonuan-pahubas (Samar Bisaya).—Sundry types of shallow fish corrals found in the coastal regions of southwestern Samar. Fish migrating shoreward during flood tide are trapped during ebb.

bonuan-palagod (Samar Bisaya).—A fish corral used in southwestern Samar.

bonuan-simongat (Samar Bisaya).—A fish corral used in southwestern Samar.

bubo (Pilipino).—Baited fish pots of different shapes and sizes made of webbed bamboo splints or chicken wire. They are provided with a nonreturn valve and a trap door for removal of the catch. In Dalaguete, Cebu Province, a floating bubo camouflaged with seaweed is used for catching flying fish.

bubo (Iloko).—A special, fine-meshed fish pot used in northern Luzon rivers for taking ipon (goby fry) and other small fish. Of cylindrical shape, it has two series of nonreturn valves. It is usually employed as a collecting device in barricades and fish shelters.

bubo-kinaban (Ilongo Bisaya).—The most common type of fish pot in the Islands. This is a cubical receptacle made of webbed bamboo splints, or more recently, of chicken wire. It has a nonreturn valve and is baited before being sunk by stone weights.

bubod (Sebu Bisaya).—A fish corral used in Dinagat, Surigao Province.

bubo-sa-aniit (Bikol).—A fish pot for catching aniit (land crabs).

bubo-sa-hipon (Tagalog).—A baited cylindrical fish pot used in Laguna for taking shrimp. Provided with two openings, each guarded by a nonreturn valve, it measures 18 by 9 inches. *Synonyms:* Tain or taing (Tag.); daing (Kap.).

bubo-sa-sira (Bikol).—A fish pot for catching various kinds of coral reef species. *Synonym:* Bubo (Pil.).

bukatot (Tagalog).—A floating bamboo fish trap in Quezon Province which is strung with banana leaves and anchored by a large rock. Of irregular cubical shape, it is 12 to 14 by 8 by 4 feet at one end, and 8 to 10 feet at the opposite end. It is kept upright by bamboo rafts used as floats above, and stones as sinkers below. The catch is removed by dip nets.

bukatot (Iloko).—Either a hoop net or a fish pot. *Synonym:* Bokatot (Ilk.).

bukatot-na-lambat (Tagalog).—A funnel-like hoop net fashioned with a nonreturn device a short distance from its circular mouth. If small, this net is placed in an opening of a paddy field dyke or dam; if large, it is used across rivers.

bukatot-na-oway (Tagalog).—A small, cylindrical fish pot for taking dalag. Made of webbed, split rattan, this flexible pot is set near the dalag nest, and the catch is made after the fish have been frightened. *Synonym:* Bikatot (Tag.).

budhi (Bisaya).—A set impounding net that filters the catch during the receding tide. Sometimes split bamboo matting is used instead of a net, and in this case the gear may be classified as a fish corral.

bugkat (Bikol and Bisaya).—A shallow-water fish corral which fishes during receding tide by straining the catch. *Synonyms:* Pahubas (Bis.); pahibas (Tag.); pabhas (Sam. Bis.).

bulos (Bikol).—A hand-thrown fish harpoon for taking rays. It consists of a spearlike blade attached to a heavy line or rope.

bumbon (Tagalog).—A fish shelter made by tying or piling together bunches of twigs, bushes, branches of trees, shrubs, and anchoring these in a desired spot. The catch is effected with the aid of textile or nontextile appliances. *Synonyms:* Bombon (Pil.); bumbon (Tag.); arong (Sam. Bis.); rama (Ilk.); tambong (Bik.); dugmon (Ak. Bis.); legma (Pang.).

bumbon-hipon (Tagalog).—A fish shelter (bumbon) for catching shrimp. This is extensively employed in Laguna de Bay where the principal species caught is the palaemon (large fresh-water shrimp). The catch is made with a salap (triangular lift net).

bungaw (Sebu Bisaya).—A large cylindrical fish pot used in Bohol Province. *Synonym:* Bubo (Tag.).

bungsod (Bisaya; Maranaw).—A general term for fish corrals in the Bisayas, especially Cebu. *Synonyms:* Baklad (Tag.); punot (Bis.; Kuy.); sagkad (Bik.); pasabing (Ilk.); bunuan (Sam. Bis.).

bunit (Bisaya).—A pole and line. *Synonyms:* Binwit or biwas (Tag.); baliwasnan (Bat. Tag.).

bunsod (Bisaya; Maranaw).—A fish corral. *Synonyms:* Bungsod (Bis.; Mar.); baklad (Tag.).

bunsod-balirong (Sebu Bisaya).—A circular fish corral used in Bohol Province. It is built in 1 to 2 fathoms of water, and fish are attracted by a powerful incandescent lamp. This gear also serves the purpose of a live-box until the catch can be removed.

bunsod-binaterol (Sebu Bisaya).—A fish corral used in Tanjay, Negros Oriental Province.

bunsod-dako (Sebu Bisaya).—A deep-water fish corral in Bohol Province.

bunsod-gamay (Sebu Bisaya).—A shallow-water fish corral in Bohol Province.

bunsod-lapad (Sebu Bisaya).—A fish corral in Kinogitan, Misamis Oriental Province, from which fish are taken by a scoop seine (sigin). *Synonyms:* Tinagala or paugmad (Bis.).

bunsod-pahubas (Sebu Bisaya).—A small, shallow-water fish corral constructed along tidal flats in Bohol and Negros Oriental Provinces. It is composed of a collecting crib and two heart-shaped, semicircular enclosures with two divergent wings. It fishes during receding tide. *Synonyms:* Pahubas (Bis.); pabhas (Sam. Bis.); pahibas (Tag.).

bunsod-paugmad (Sebu Bisaya).—A deep-water fish corral with a leader, two wings, a large, semicircular enclosure, but without collecting cribs or pound. The catch is made with a sigin (scoop seine). *Synonyms:* Paugmad (Bis.); tinagalog (Seb. Bis.).

bunsod-sahid (Sebu Bisaya).—A fish corral used in Siquijor, Negros Oriental Province.

bunsod-tinagalog (Sebu Bisaya).—Deep-water fish corrals used in Lanao and Agusan Provinces. These have no collecting cribs, and the catch is brailed out directly from the korona (semicircular enclosure) with a sigin (scoop seine). *Synonyms:* Bunsod-paugmad (Seb. Bis.); paugmad (Bis.).

bunsol (Samal).—General term for all types of fish corrals. *Synonyms:* Baklad (Tag.; Kap.); sagkad (Bik.); pasabing (Ilk.); punot (Il. Bis.); bunuan (Sam. Bis.); bungsod (Seb. Bis.).

buntog (Samar Bisaya).—An encircling gill net into which fish are scared by wood plungers. It is operated from bancas. Literally, the term means dropping something heavy. *Synonym:* Kayagkag (Bis.).

bunuan (Bikol).—An ordinary fish corral with one heart-shaped, semicircular enclosure, a collecting crib, two wings, and a leader. *Synonym:* Kilo-kilo (Bik.).

bunuan (Samar Bisaya).—A fish corral. *Synonyms:* Baklad (Tag.); sagkad (Bik.); pasabing (Ilk.); bonuan (Bis.); punot or bungsod (Bik.); bunsol (Sa.).

bunuan-pahubas (Samar Bisaya).—A fish corral that fishes during receding tide. *Synonyms:* Pabhas (Sam. Bis.); pahubas (Bis.); pahibas (Tag.).

bunuhan (Tagalog).—A shallow river fish corral used especially for taking shrimp. It has one collecting pound and two wings but no leader, and it filters the catch carried by the current.

burayok (Iloko).—A barricade for catching ipon (small gobies). Hoop nets of sinamay and fish pots are used as collecting devices at various gates. *Synonym:* Pamalibtokan (Ilk.).

busbos (Ibanag).—A rectangular lift net for catching bangos fry. Made of sinamay, it is mounted on a bamboo frame. *Synonyms:* Dusdos (Ilk.); kasag (Tag.; Pang.; Ilk.); kasad (Ilk.).

butas-baklad (Tagalog).—A fish corral for taking mullet constructed in Butas River, principal outlet of Lake Naujan, Mindoro Province. It consists of two long wings leading to an almost circular enclosure flanked by two collecting pounds for brailing out the catch.

butong (Sebu Bisaya).—A drive-in-net for reef species. Its pocket is a small seine into which fish are driven with scarelines made of coconut leaves which may also serve as wings. *Synonyms:* Bahan (Sam. Bis.); baling-lukay (Sam. Bis.).

buya (Bikol-Spanish).—Anchored bamboo rafts used in Tabaco Bay and Albay Gulf, Albay Province, for luring fish, especially round scad, into seeking shelter. The catch is made with a triangular skimming net. *Synonyms:* Sapyaw-sa-buya (Bik.-Sp.); sapyaw (Bik.).

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kabitenyo (Bikol-Spanish).—A deep-water fish corral used in Sorsogon Bay and vicinity.

kabyaw (Samar Bisaya).—A set blanket net for taking coral-reef species, especially *caesios*. It is used with the aid of one small dugout canoe. *Synonym:* Paduyan (Il. Bis.).

kabyaw (Bikol).—A round haul seine used in Ragay Gulf, especially near Pasacao and Masbate, for catching sardines, anchovies, and mackerel. It is operated with an incandescent lamp during the dark of the moon. *Synonyms:* Sapyaw (Pil., except Albay Province); lawag (Sam. Bis.); iwag (Il. Bis.); sapyaw-kon-luses (Bis.-Sp.).

kabyaw-kon-luses (Bikol-Spanish).—A round haul seine operated with the aid of lights in the Bikol region, especially Ragay Gulf and San Miguel Bay. *Synonyms:* Sapyaw (Pil.); lawag (Sam. Bis.); iwag (Il. Bis.); sapyaw-kon-luses (Bis.-Sp.).

kabyaw-ha-salog (Samar Bisaya).—A square lift net used in rivers by four men from four bamboo tripods, one at each corner of the net. *Synonyms:* Konay (Sam. Bis.); salambaw (Samb.; Bik.-Tag.; Bis.).

kabyaw-ordinaryo (Bikol-Spanish).—A round haul seine operated in San Miguel Bay by daylight. *Synonym:* Sapyaw-de-kuwerdas (Sam. Bis.).

kakayang (Ivatan).—A long-handled dip net made with coarse mesh for catching crabs. It measures 12 to 18 feet long and about 2 feet in diameter at the mouth.

kafu (Ibanag).—A push net for catching ipon (goby fry). *Synonym:* Kapot (Ilk.).

kaladkad (Tagalog).—A dredge net for catching snails in Laguna de Bay. *Synonyms:* Pakaladkad, kaladkad-ng-suso, kulakod (Tag.).

kalamba (Samar Bisaya).—A gill net used in southwestern Samar for taking mullet, mojarras, goatfish, plotosid catfish, etc.

kalaskas (Kapampangan).—A fish rake for catching shrimp in rivers. Made of bamboo, it is operated by one man alongside a boat in wading depths. The catch is made simply by scaring the shrimp into jumping aboard the tilted boat. *Synonyms:* Lawiswis (Tag.); kalaykay (Tag.-Bik.).

kalaskas (Iloko).—A submerged scareline used as an impounding device for catching gobies, mullet, silvery grunts and similar fish. It is made of banana stalks or nipa palm leaves and stones alternating on a rope. The catch is picked up by hand after the fish have been frightened into the enclosure by beating on the enclosed surface.

kalaskas (Pangasinan; Pilipino; Tagalog).—A drive-in-net without a pocket. Usually made of sinamay, it is used with a scareline. *Synonyms:* Kulokutok or katigbi (Tag.).

kalaykay (Tagalog-Bikol).—A rake used for catching shrimp in Camarines Norte Province. *Synonyms:* Kalaskas (Kap.); lawiswis (Tag.).

kaligid (Sebu Bisaya).—A cylindrical bamboo fish pot.

kalinawan (Sebu Bisaya).—A fish corral used in Agusan Province.

kalong (Illongo Bisaya).—An encircling gill net used in Balete, Capiz Province. *Synonym:* Kayagkag (Bis.).

kalubkob (Sambal).—A fish corral that fishes during receding tide as fish migrate back to deeper waters. It is designed with two wings flanking a collecting crib at the center. *Synonyms:* Pahibas (Tag.); pahubas (Bis.).

kalukor (Pangasinan).—A cotton netting drag or beach seine which has no pocket. *Synonyms:* Karukod or karorukod (Iban.; Ilk.); sinsoro (Tag.-Sp.); pukot (Tag.); karurokod (Iban.).

kamlad (Ilongo Bisaya).—A large or medium-sized cotton netting drag seine used in Estancia, Iloilo Province.

kammag (Iloko).—A fine-meshed beach seine having a bag or pocket for catching siganid fry.

kammang (Ibanag; Iloko; Pangasinan).—A gill net operated from a banca.

kansisi (Tagalog).—A set gill net for sardines. It is a smaller version of the largarete (Tag.-Sp.).

kantil (Samal; Taw Sug).—A tuck seine fished with lights in Jolo Province.

kapit (Tagalog).—A push net used in Nueva Ecija Province. *Synonym:* Sakag (Tag.).

kapot (Iloko).—A push net of sinamay operated by one man pushing and lifting from time to time. Smaller than the sayot (Ilk.), it measures 6 by 9 feet and is mounted on a triangular frame. *Synonyms:* Dusdos (Ilk.); sayursor (Samb.).

karaynas (Iloko).—A drive-in-net for catching mullet. It is set across a river, and the fish are driven from upstream by means of another net serving as the scareline. *Synonyms:* Dundon or genned-palagto (Ilk.).

karik (Pangasinan).—A pole and line. *Synonyms:* Binwit or biwas (Tag.).

karukal (Kuyonon).—A squid jig. Leaded and plumblike, this jig is attached to a retrieving string at the larger end and a ring of barbless, baited hooks tied by the shanks to the smaller end.

karukod (Iloko).—A drag or beach seine made either of sinamay or cotton netting with or without a bag or pocket. It is smaller than the daklis (Ilk.). *Synonyms:* Salap (Bis.; Tag.); sinsoro (Pil.-Sp.); pukot (Tag.); sarap (Bis.); baling (Sam. Bis.).

karukod (Pangasinan).—A drag seine without a pocket. *Synonyms:* Karudkod or kurokod (Ilk.).

karudkod (Iloko).—A drag or beach seine of sinamay or cotton netting with or without a pocket. *Synonyms:* Karukod (Ilk.); kalukor (Pang.).

karurokod (Ibanag).—A drag or beach seine of cotton netting provided with a pocket. *Synonym:* Kalukor (Pang.).

karwas (Iloko; Ibanag).—A scoop made of matted bamboo splints.

kasad (Iloko).—A rectangular lift net provided with a pocket. Mounted on a bamboo frame, it is operated by one man with an inverted, T-like bamboo or wooden plunger used to scare the fish into the net. *Synonym:* Kasag (Tag.).

kasag (Tagalog).—A rectangular lift net used for catching fresh-water shrimp in Lake Sampaloc, Laguna Province. Made of sinamay and mounted on two bamboo crosspieces, it is operated by one man with the aid of an inverted, T-like plunger. *Synonym:* Kasad (Ilk.).

kasag (Iloko; Pangasinan).—A rectangular drive-in net used with a scareline. *Synonym:* Kulokutok (Tag.); odaod (Ilk.).

kaskasad (Iloko).—A rectangular framed lift net operated by one man with an inverted, T-like plunger. *Synonyms:* Kasad (Ilk.); kaskasag (Pang.).

kaskasag (Pangasinan).—A one-man rectangular lift net.

kataw (Samar Bisaya).—Longlines used in Samar Province. *Synonym:* Kitang (Tag.).

katev (Ivatan).—A crab trap. A wooden boxlike receptacle, having the entrance guarded by a trap door which is controlled by a baited string. The crab, crawling out of its burrow when attracted to the bait, pulls the string which releases the door, and is then trapped.

katigbi (Tagalog).—A drive-in net used in wading depths chiefly for taking mullet. It is a rectangular piece of fine-meshed cotton netting held by two men. Fish are driven by a long scareline operated by two other men. *Synonyms:* Kulokutok or patibok (Tag.).

kawad (Sebu Bisaya).—Handlines used in Agusan Province.

kawag (Ilongo Bisaya).—Simple handlines used with lights. *Synonym:* Tunton (Ak. Bis.).

kawil (Pilipino).—Handlines or drop lines used with or without lights.

kawil-pangpusit (Batangas Tagalog).—A squid jig used in Batangas. *Synonyms:* Lukon-lukon (Bis.); ulang-ulang (Seb. Bis.; Sa.); hila-hila (Il. Bis.).

kaw-it (Iloko; Sebu Bisaya).—Gaffs used in Ilocos Norte Province and in Sebu Bisaya speaking regions.

kaw-it (Sebu Bisaya).—A gaff used for landing fish in trolling operations.

kayakas (Tagalog; Pangasinan).—A drive-in-net of sinamay into which reef species are driven with a kayakas (scareline). It is a local version of the muro-ami and also is similar to the bahan (Sam. Bis.). *Synonym:* Kayakas-boholano (Tag.).

kayakas-boholano (Tagalog).—A drive-in net in Pagbilao, Quezon Province, so called because fishermen from Bohol introduced it. *Synonyms:* Kayakay (Tag.); kayakas (Tag.; Pang.).

kayakay (Tagalog).—A drive-in net used in Padre Burgos, Quezon Province. *Synonym:* Kayakas (Tag.; Pang.).

kayagkag (Bisaya).—An encircling gill net of cotton netting which measures from 100 to 300 by 8 feet. Fish are forced to gill by beating the enclosed space with a wooden plunger. This is a smaller version of the bating or halang (Tag.).

kayagkag-pahubas (Sebu Bisaya).—A gill net of cotton netting used in Bohol Province chiefly for tigi (deep-bodied anchovies). It is payed out during high tide across the path of the fish, and the catch is effected during receding tide as the fish migrate seaward.

kayagkag-pamalo (Sebu Bisaya).—A gill net for taking balo (garfish) in Negros Oriental Province.

kayagkag-pamansi (Sebu Bisaya).—A gill net used in Bohol Province for catching bangsi (flying fish).

kaykag (Ilongo Bisaya).—An encircling gill net used in Balete, Capiz Province. *Synonym:* Kayagkag (Bis.).

kileb (Iloko).—A river barricade used in the Iloko Provinces for catching fish migrating downstream. It is made of bamboo matting staked in a V-shape and has an inclined platform at the center. *Synonyms:* Azar (Ilk.); patulid-kileb (Ilk.).

kilo-kilo (Tagalog).—A series of low, semicircular enclosures set across an indentation in Laguna de Bay for catching dalag. Made of bamboo matting measuring 3 by 3 feet, these are arranged to overlap in chain formation. At intervals of 17 to 23 of these mats are heart-shaped collecting cribs which may number as many as 35 in a unit.

kilo-kilo (Bikol).—An ordinary fish corral with a heart-shaped enclosure, a collecting crib, two wings, and a leader. *Synonym:* Bunuan (Bik.).

kiming (Kuyonon).—A small cubical fish pot used in Palawan Province. *Synonyms:* Timing (Bis.); paniming (Seb. Bis.).

kimpot (Kapampangan).—A cylindrical fish pot for shrimp similar to the tapangan (Tag.). This type has only one nonreturn valve, and the opposite end tapers to a narrow opening provided with a stopper.

kinabite (Bikol).—A fish corral of the agila (Tag.) type used in Ragay Gulf and San Miguel Bay. It has a large semicircular enclosure leading into the collecting crib at one side. Cavite fishermen introduced it into this area. *Synonyms:* Agila (Tag.); inangkla (Sam. Bis.).

kitang (Tagalog; Pangasinan; Iloko; Sambal).—General term for longlines.

kitang-pangkanduli (Tagalog).—Set longlines in Laguna de Bay for catching kanduli (ariid catfish).

kitang-pangdalag (Tagalog).—Set longlines used in Laguna de Bay for catching dalag (murrel).

kitay (Tagalog).—Longlines used in Naujan, Mindoro Province. *Synonym:* Kitang (Tag.).

kiteb (Iloko).—A barricade for catching fish migrating downstream in the rivers of La Union Province. *Synonym:* Kileb (Ilk.).

kitid (Kapampangan).—A drift net used in Pampanga Province.

kitid (Aklan Bisaya).—An encircling gill net of cotton for catching mullet fingerlings and other species of similar size.

kitig (Tagalog).—A drive-in net used in Looc, Mindoro Province.

kolorado-koral (Bisaya-Spanish).—A fish corral used in Agusan Province.

konay (Samar Bisaya).—A drive-in net used in Basey, Samar Province, chiefly for mullet. Mounted on a triangular frame, it has no runners and is fished in wading depths with a long scareline. *Synonyms:* Solambaw or sulambaw (Sam. Bis.).

konay (Sambal).—A drive-in net used with a scareline.

konukon (Iloko).—A fish shelter made by piling stones in an excavation in the bed of a stream. Fish are caught by various textile and non-textile devices or by hand. *Synonyms:* Bumbon (Tag.); rama (Ilk.); arong (Sam. Bis.).

Konurona (Dabawenyo).—A fish corral of the agila (Tag.-Sp.) type which has one large semicircular enclosure with or without collecting cribs. In the latter case, brailing is done with a scoop seine.

koral-boholano (Bikol-Tagalog).—A fish corral introduced in Ragay Gulf by Bohol fishermen. Instead of the usual semicircular enclosure, this type has a chamber formed in five angles.

kubkob (Bisaya-Tagalog).—A purse seine or impounding net used to catch pelagic species that run in schools, such as anchovies, sardines, and mackerel. Capture is effected by surrounding the school, pursing the bottom line, and concentrating the catch at the landing piece, where the fish are brailed out. *Synonyms:* Panghasa-hasa, talakop, talakob (Tag.).

kubkob (Bikol).—A stop seine used in San Miguel Bay for taking large concentrations of ariid catfish, snappers, and grunts.

kubkobilyo (Samar Bisaya-Spanish).—A round haul seine used in Samar Province for catching pelagic species with the aid of light. It is much smaller than the sapyaw (Pil.). *Synonyms:* Langbat (Sam. Bis.); sangab (Seb. Bis.).

kubkob-patiyoy (Bisaya).—A two-boat round haul seine for catching mackerel during the dark of the moon. Similar to but much larger than the kubkub-simbada (Bis.), it measures 125 by 15 fathoms, with a mesh of 2½ inches, stretched at the bunt, and 3½ inches at the wings.

kubkob-simbada (Bisaya).—A one-boat round haul seine—actually a combination of round haul seine and gill net—for catching mackerel during the dark of the moon. It measures 50 by 10 to 12 fathoms. At the bunt, it has a mesh of 2 inches stretched, and 6 inches in other portions.

kubo (Iloko).—A somewhat rectangular fish trap set in quiet, secluded coves for taking dalag. Made of coarse split bamboo stakes, it is fashioned like the roof of a house and measures about 2½ by 2 by 1½ feet. The entrance has a trap door which is released by a triggerlike device, once the fish have been lured in it for nesting purposes.

kubong-kubong (Iloko).—A fish corral in the Iloko provinces.

kulakod (Tagalog).—A dredge net for collecting ark shells. It consists of a pair of wooden skids between which the lower frame of the mouth has a rakelike device. A bag net is trailed from behind. This gear is pulled from a banca anchored some distance away. *Synonym:* Kaladkad (Tag.).

kulokutok (Tagalog).—A drive-in-net used chiefly for catching mullet. Of rectangular shape, it is generally set away from shore, and fish are driven toward it by a scareline. *Synonyms:* Katigbi (Tag.); kalaskas (Pil.).

kulong (Bisaya; Maranaw).—A small bamboo trap set in quiet, secluded spots for taking dalag. The trap door is released by the fish touching a triggerlike device at the entrance. *Synonyms:* Paluob or pataob (Tag.).

kulong (Iloko).—A fish shelter set along river banks or in rice fields for luring dalag. It consists of an excavation enclosed by an earthen dike with a narrow gate. The catch is made with a cast net or cover pot after the debris has been cleared. *Synonym:* Luong (Tag.).

kurikan (Batangas Tagalog).—Troll lines used in Batangas Province.

kurokod (Iloko).—A drag seine, 100 to 150 fathoms long, used in the northern or Iloko provinces. It is smaller than the daklis (Ilk.). *Synonym:* Karukod (Ilk.).

kurokod-partigo (Iloko).—A round haul seine of partigo (sinamay). *Synonyms:* Sapyaw (Pil.); sayanggong-sapyaw (Ilk.).

kurokutok (Batangas Tagalog).—A triangularly framed push net for catching mullet. Made without runners, it is set in an inclined position and operated with a scareline. *Synonym:* Daplis (Bat. Tag.).

kurokutok (Banton Bisaya).—A drive-in-net for catching mullet. It consists of a somewhat rectangular set net and is used with a scareline.

D

dakikong (Tagalog).—A small, heart-shaped baited fish pot used for catching clariid catfish (hito) in Paete, Laguna Province, and Kainta, Rizal Province. *Synonyms:* Bakikong, siid, umang (Tag.); tarik (Ilk.); dagwan (Tag.).

daklis (Iloko; Pangasinan; Sambal).—A large beach or drag seine of cotton netting. Made with a bag or pocket, it is 100 to 150 fathoms long. It is smaller than the biray (Ilk.) but larger than the karukod (Ilk.). *Synonyms:* Sinsoro (Tag.-Sp.); pukot (Tag.); salap, baling, baring (Bis.).

daklis (Batangas Tagalog).—An encircling gill net for taking sardines in Batangas Province.

daklis-a-linas (Iloko).—A drag seine fished with a scareline.

daklis-de-ipon (Iloko).—A drag seine designed and operated especially for catching ipon (young gobies) along the coast of northern Luzon. Made of sinamay, it is similar to but much smaller than biray-kon-daklis (Ilk.).

dagdag (Iloko).—A barricade used in Paniqui, Tarlac Province, for catching ipon (young gobies). *Synonym:* Asar (Ilk.).

dagukdok (Sebu Bisaya).—A simple handline fished with lights.

dagwan (Tagalog).—A potlike fish trap used in Paete, Laguna Province, exclusively for the catching of hito (clariid catfish). It is fished with strong-smelling bait. *Synonym:* Dakikong (Tag.).

da-ing (Kapampangan).—A cylindrical fish pot. *Synonyms:* Taing, tain, or bubo-sa-hipon (Tag.).

dala (Tagalog).—General term for cast nets. *Synonyms:* Laya or yaya (Bis.); sabukol (Pang.); tabukol (Ilk.); ataraya (T. Sug.; Sa.); raya (Sam. Bis.).

dala-pamulanguso (Tagalog).—A deep-water cast net used in Manila Bay for catching small sardines. Operated from a banca, it is made of linen twine knitted with a mesh of ⅝-inch, stretched.

dala-pang-alangan (Tagalog).—A deep-water cast net operated in Manila Bay for taking medium-sized sardines. Fished from a banca, it is made of linen twine knitted with a mesh of ⅞-inch, stretched.

dala-pangbakuko (Tagalog).—Cast nets used in Bataan Province for catching bakoko (porgies and grunts). Made of wide-meshed coarse twine, it is operated by casting over fish previously lured into a pile of stakes.

dala-pangdalag (Tagalog).—A cast net fished in Laguna de Bay for dalag (murrel). Usually knitted of No. 20 sewing thread, it is 2 to 3 fathoms deep.

dala-pangduhay (Tagalog).—A cast net for impounding duhay (pomfrets). It is fashioned of China grass knitted with meshes 3½ inches, stretched, and has an opening at the apex through which the floated bait line is retrieved.

dala-pangkanduli (Tagalog).—Cast nets used in Laguna de Bay for taking kanduli (ariid catfish). Usually knitted of No. 40 Alexander sewing thread, they are 3 to 5 fathoms deep.

dala-pangsilinyasi (Tagalog).—A deep-water cast net fished in Manila Bay for silinyasi (sardine fingerlings). It is made of linen twine knitted with meshes of ½-inch, stretched.

dala-sundol (Tagalog).—A cast net used in Zaragoza, Nueva Ecija Province.

da'lis (Iloko).—Contraction of "daklis." This is a drag or beach seine hauled from the deeper to the shallower waters in gradually shelving, smooth sandy or muddy shores.

daplak (Ilongo Bisaya).—Fish pots in Negros Occidental Province which are small, flat, and have a shoelike shape.

daplis (Batangas Tagalog).—A triangular drive-in-net which is designed like a push net, but without runners, and is operated with a scareline. *Synonym:* Kurokutok (Bat. Tag.).

darilay (Ibanag).—General term for longlines in the Cagayan Valley, northern Luzon. *Synonym:* Kitang (Tag.).

dayakos (Tagalog).—A sinamay filter net operated in river mouths for taking alamang (small shrimp) during flood and hipon (larger shrimp) during ebb. In Laguna de Bay, the term refers to an impounding net similar to a drag seine, which is middled or split at several points until the enclosed space is reduced to a very narrow, elongated enclosure. The fish are then picked up by hand.

dayakos (Iloko).—A term for dip nets in Ilocos Norte Province.

dayos (Iloko).—A small drag seine. *Synonyms:* Sagap (Ilk.; Bis.; Bat. Tag.); panagap (Tag.).

dayusdos (Iloko).—A push net used in Agoo, La Union Province. *Synonyms:* Sakag (Tag.); dusdos (Ilk.).

dinumpil (Samar Bisaya).—A pangalato type of shallow-water fish corral found in Leyte Province. It is fashioned with angular enclosures instead of the conventional semicircular types. *Synonym:* Dinungpil (Sam. Bis.).

dinungpil (Samar Bisaya).—A fish corral used in Calbiga, Samar Province, which is of the pangalato type and has angular enclosures rather than the ordinary semicircular types. *Synonym:* Dinumpil (Sam. Bis.).

diyakos (Tagalog).—A filter net operated in river mouths for taking alamang (small shrimp). *Synonyms:* Dayakos, sala, limpot, lumpot (Tag.).

dudok (Ivatan).—A dip net used in Batanes Province for catching flying fish. It is operated with a light.

dugmon (Aklan Bisaya).—A fish shelter. *Synonyms:* Bumbon (Tag.); padugmon (Ak. Bis.); bombon (Pil.).

dulon (Iloko).—A drag seine used in Ilocos Sur Province for catching ipon (goby fry). *Synonym:* Daklis-de-ipon (Ilk.).

dumaga (Sebu Bisaya).—A fish corral found in Balamban, Cebu Province. *Synonym:* Dumalaga (Seb. Bis.).

dumalaga (Sebu Bisaya).—A fish corral in Balamban, Cebu Province. *Synonym:* Dumaga (Seb. Bis.).

dumpil (Sebu Bisaya).—A movable fish trap set at the head of a canal to entice dalag (murrel). Semicircular in shape, it consists of two strips of split bamboo matting. In Ubay, Bohol Province, the term refers to a small mobile fish corral.

dundon (Iloko).—A drive-in-net set across rivers in northern Luzon chiefly for taking mullet. The fish are driven by dragging an auxiliary seinelike net used as a scareline. *Synonyms:* Karaynas, genned-palagto (Ilk.).

dusdos (Iloko).—A small push net of sinamay for catching ipon (goby fry). It is larger than the sayot (Ilk.). *Synonym:* Kapot (Ilk.).

dyakos (Tagalog).—A filter net for taking shrimp. *Synonyms:* Dayakos, sala, limpot, and lumpot (Tag.).

E

e-erew (Ivatan).—A hand instrument in the form of a hook for catching tabunong (octopus). The gear is similar to panukot (Tag.).

ese (Sebu Bisaya).—A three-pronged fish spear used in northern Mindanao for catching sanga (devil ray). The spear is attached to a line.

esparabel (Bisaya-Spanish; Ibanag-Spanish).—A cast net in Antique and Cagayan Provinces. *Synonyms:* Dala (Tag.); laya (Bis.); tabukol (Ilk.); sabukol (Pang.); ataraya (T. Sug.; Sa.).

etter (Iloko).—A barricade used in northern Luzon rivers for catching ipon (goby fry). *Synonym:* Better (Ilk.).

etter-pamobuan (Iloko).—A barricade for catching ipon (goby fry) in northern Luzon. The collecting portions of this gear are bubo (fish pots) of very fine mesh.

etter-panayotan (Iloko).—A barricade for catching ipon (goby fry) in Tagudin, Ilocos Sur Province. A sayot (small push net) is the collecting device used.

G

gakit (Sebu Bisaya).—A fish shelter in Argao, Cebu Province. It consists of an anchored bamboo raft for luring the fish and a skimming net for hauling the catch. Sometimes the fish are taken by various other textile or non-textile devices. *Synonyms:* Sapyaw (Bik.); buya (Tag.-Sp.).

galay (Tagalog).—A pole and line for catching dalag. The pole is 6 to 15 feet long and the line 3 to 9 feet in length. Usually baited with live frog, it is fished from shore or from a banca by trailing the hook back and forth. *Synonym:* Liwliw (Ilk.).

gangen (Ibanag).—A fish pot for catching mullet in rivers of Cagayan Province. This gear is made to drift with the current. *Synonyms:* Pateng (Ilk.); pareng (Ilk.; Iban.).

gango (Sebu Bisaya).—A set gill net hung under an anchored bamboo raft. The raft lures the fish, which are then gilled by the net.

garamgam (Iloko).—A drag seine used along the shore and rivers of La Union Province. It is similar to, but much smaller than the daklis-de-ipon. *Synonym:* Garemgem (Ilk.).

garemgem (Iloko).—A beach or drag seine. *Synonym:* Garamgam (Ilk.).

garong (Sebu Bisaya).—A blanket net. *Synonym:* Paduyan (Bis.).

gayad (Tagalog; Sambal).—A small scoop seine, similar to a purse seine, which is used to scoop the catch directly from the semicircular enclosures of deep-water fish corrals. *Synonyms:* Sigin (Pil.); sagad (Seb. Bis.).

gayang (Ivatan).—A fish spear in the Batanes Islands consisting of five barbed metal blades attached to a wooden handle by a somewhat cylindrical solid wooden base.

genned-palagto (Iloko).—A lift net used in rivers for taking mullet. Set across the river, the mullet are driven in from upstream by dragging an accessory seine which functions as a scareline. *Synonym:* Dundon or karaynas (Ilk.).

ginantso (Bisaya-Spanish).—An encircling gill net of cotton twine similar to the banata (Sam. Bis.).

gulgo (Sebu Bisaya).—A fish shelter consisting of a bamboo raft to which coconut leaves are attached. It is anchored in the sea and sometimes fished at night with lights. The catch is made with a sigin (scoop seine). *Synonym:* Payaw (Seb. Bis.).

gulgol (Samar Bisaya).—A small drag or beach seine in Samar and Bohol Provinces.

gulgol (Sebu Bisaya).—A barricade of stones for catching rock fish. Built on reefs, it filters the catch into a collecting device at the gate during ebbtide.

gulgol-sa-anga (Sebu Bisaya).—A triangular-shaped barricade used in northern Mindanao for catching anga (goby). The collecting portion, made of thickly-woven cloth or sack cloth, measures 9 by 5 feet.

gulgol-sa-igdidili (Sebu Bisaya).—A set or staked filter net for catching young gobies migrating upstream. Made of sinamay, it is flanked by a pair of barricadelike wings of bushes, leaves, trees, and stones.

guma (Samar Bisaya).—A fish shelter constructed of bunches of twigs, leaves, and other debris. The catch is effected by surrounding the shelter with sundry textile or non-textile devices. *Synonyms:* Bumbon (Tag.); rama (Ilk.); bombon (Pil.).

guyod (Sebu Bisaya).—A troll line. *Synonyms:* Pahila (Tag.); sibidsibid (Tag.; Bik.; Bis.); yambo (Ak. Bis.; Ban. Bis.).

H

habay (Tagalog).—A longline used in Laguna de Bay for catching kanduli (ariid catfish).

habing-ng-dulong (Tagalog).—A movable fish trap used in Laguna de Bay for surrounding schools of dulong (young gobies). It is made of split bamboo matting, and the catch is effected by a sinamay drag seine.

habog (Samar Bisaya).—A deep-water fish corral found in Basey, Samar Province. It is 7 to 8 fathoms deep and may or may not have a collecting crib. In the latter case, a sigin (scoop seine) is used for brailing. *Synonym:* Paugmad (Bis.).

halakob (Sambal).—A cover pot. *Synonym:* Salakab (Tag.).

halang (Tagalog).—An encircling gill net used during daylight in Manila Bay for catching sardines. It is fashioned of cotton twine with a vertical run of meshes in relation to the cork and lead lines. Upon the introduction of the sapyaw (Pil.), this gear became obsolete; however, the term is commonly used in Cavite. In Bataan Province, it refers to a drag seine—made of China grass and provided with a pocket—for catching aguot (spotted grunt) and mayang (drepane). *Synonym*: Bating (Tag.).

hampas (Bisaya).—A fish shelter usually built on coral reefs and made of bunches of twigs and other non-textile materials. The attracted fish are confined either by a net or by split bamboo matting, and after the debris is cleared, the catch is made by various means, including picking up by hand. *Synonyms:* Bumbon (Tag.); rama (Ilk.); bombon (Pil.).

hampas-lag-e (Sebu Bisaya).—A fish corral found in Siquijor, Negros Oriental Province.

hangpas (Sebu Bisaya).—A fish shelter set on coral reefs in Dapitan, Zamboanga Province. Various means are used to impound and to haul in the catch. *Synonyms:* Hampas (Bis.); bumbon (Tag.); bombon (Pil.).

hanig (Bisaya).—A drive-in-net used in Badajos, Romblon Province. It is operated with a scareline. *Synonyms:* Kulokutok (Tag.); linge (Ak. Bis.).

hapin (Tagalog).—General term for lines in Tayabas and Batangas Provinces. Specifically, it refers to handlines and troll lines.

hapon (Taw Sug; Samal).—Handlines and troll lines in the Sulu Archipelago.

harpon (Sebu; Bisaya-Spanish).—A fish spear in the form of a bow-gun, the arrowlike blade of which is released by a triggerlike device.

hasang-antigo (Ilongo Bisaya).—A type of fish corral, supposedly of old design, which is used in western Visayas. It is constructed with two entrances, a leader, two wings, a somewhat rectangular forechamber, a semicircular enclosure, and a smaller triangular chamber leading to the heart-shaped terminal pound.

hasang-moderno (Ilongo Bisaya).—A fish corral used in western Visayas. Although similar to the hasang-antigo (Il. Bis.), it is designed with four entrances and a triangular forechamber. The latter provides three entrances to the semicircular enclosure instead of the usual two.

hasang-simple (Ilongo Bisaya).—A simple type of fish corral in western Visayas. A long leader guides the fish into a semicircular enclosure, on one side of which is a platform and a winglike extension of the fence. On the other side is a plane-peaked pyramidlike collecting chamber which has a platform on its three sides for the brailing out of the catch with a scoop seine.

hayhay (Batangas Tagalog).—A set longline. Strictly speaking, the term denotes one skate or basket or unit of a longline.

hibasan (Tagalog).—Barricades of stones built on coral reefs along shores. Fish are held back of this during receding tide and are collected in various ways.

hikog (Aklan Bisaya).—A snare for catching large shrimp by the abdomen. The noose is made of fine coir twine tied to the tip of a small bamboo pole.

hiktas (Samar Bisaya).—A small river fish corral. It is composed of a leader and a semicircular enclosure, one side of which is blind with only a short extension forming a wing. The other side leads into a heart-shaped chamber terminating in a collecting crib where the catch is brailed out.

hiir (Sambal).—A baited, potlike fish trap for taking clariid catfish. It is heart-shaped and made of bamboo matting. The term is commonly used in northern Zambales Province from Iba northward. *Synonyms:* Siid, bakikong (Tag.).

hila-hila (Kapampangan; Tagalog).—A small drag seine for catching shrimp in Manila Bay, particularly in Tinajeros, Pampanga Province. Operated by only two men in waters around 1 fathom deep, it has a long pocket and two short wings.

hila-hila (Ilongo Bisaya).—A wooden squid jig shaped like a shrimp. Barbless hooks are attached near its "tail," and it is fished by occasionally jerking as it glides through the water. *Synonyms:* Kawil-pangpusit (Tag.); lukon-lukon (Il. Bis.); ulang-ulang (Seb. Bis.; Sa.).

hukog (Sebu Bisaya).—A fish corral used in Cebu Province.

hud-hod (Bisaya; Bikol).—A push net, usually made of sinamay, for catching small shrimp. *Synonyms:* Sakag (Tag.); sudsod (Bis.).

hug-hog (Sebu Bisaya).—A handline used in Bohol Province.

hulod (Samar Bisaya).—A fish corral in Samar Province.

hulog-hulog (Sebu Bisaya).—Handlines used in Santander, Cebu Province.

hulyang (Sambal).—A river barricade for catching ulang (fresh-water shrimp).

huyod (Sebu Bisaya).—A fish corral found in Cebu Province.

I

ililikos (Sebu Bisaya).—A beach or drag seine. *Synonyms:* Pukot (Tag.); sinsoro (Tag.-Sp.).

inangkla (Bisaya; Bikol).—A fish corral in the Visayas and southern Luzon which has an anchor-shaped ground plan. It is similar to the angkla type of fish corrals in Manila Bay.

ingog-bahan (Sebu Bisaya).—A long-haul beach seine used in Loon, Bohol Province. It is payed out some distance from shore and hauled toward the shallow beach.

isol-isol (Kuyonon; Tagbanwa).—A drive-in-net. It is mounted on a triangular push net type of frame and has no runners. A scareline is used in its operation.

ivoya-sakag (Ivatan).—A push net used in Batanes Province. *Synonyms:* Sakag (Tag.); hud-hod and sudsod (Bis.).

iwag (Ilongo Bisaya).—A two-boat round haul seine for catching pelagic species that run in schools, such as anchovies, sardines, and mackerel. Made of cotton twine, it is fished with lights during the dark of the moon. *Synonyms:* Sapyaw (Pil.); lawag (Sam. Bis.); sapyaw-kon-luses (Sam. Bis.-Sp.); kabyaw (Bik.).

L

labang (Sebu Bisaya).—A barricade in Dalaguete, Cebu Province.

labay (Ilongo Bisaya).—Longlines. The term also refers to the scareline used with drive-in-nets and trap nets. *Synonym:* Kitang (Tag.).

laklak (Sebu Bisaya).—A trap net in San Juan, Negros Oriental Province.

lagi (Sebu Bisaya).—A fish corral used in Bohol Province.

lagpit (Ilongo Bisaya).—A one-bamboo-joint crab trap used in catching land crabs as they come out of their burrows. *Synonyms:* Patibong (Tag.); yagpit (Ak. Bis.); sarading (Kuy.).

lala (Sambal; Pangasinan).—A term for cast nets in general.

lama (Pangasinan).—A fish shelter made of piles of debris. *Synonyms:* Bumbon (Tag.); rama (Ilk.); bombon (Pil.).

lamba (Ilongo Bisaya).—An encircling gill net used with a scareline.

lambat (Ilongo Bisaya).—A purse seine. Brought by the Tagalog to the Visayas, the term originally denoted a net. *Synonym:* Kubkob (Bis.).

lambay (Ilongo Bisaya).—A barricade. Sometimes this term signifies simple rectangular nets used to bar the course of the fish.

lambo (Bisaya; Samal).—A handline or drop line. Strictly speaking, the term applies to the act of using this gear. *Synonym:* Kawil (Tag.).

lambonin (Samal; Taw Sug).—A shallow-water fish pot without bottom or floor. *Synonym:* Bubo (Tag.).

lampara (Bisaya-Spanish).—A bag net of sinamay somewhat similar to the basnig (Tag.). It is operated from two parallel bancas joined by bamboo outriggerlike braces to form a square rig. It is fished with the aid of light during the dark of the moon. The Spanish word "lampara" denotes light, and in Mindanao the term generally refers to fishing with light.

lampara-kon-sigpaw (Sebu Bisaya).—A sigpaw (dip net) used in scooping fish attracted by light.

langbat (Samar Bisaya).—A round haul seine used in Samar. Like lambat (Il. Bis.), the term is a Tagalog word for net. Later it was used to denote a purse seine in Samar, perhaps the same net Tagalog fishermen brought to the region—a talakop (Tag.). Still later, Samar fishermen found they could catch fish (especially mackerel) just as well without pursing the bottom.

lantaw (Taw Sug; Samal).—A gill net used for catching sardines. It is made of cotton sewing thread knitted with a mesh of 2 inches, stretched; and it measures 17 by 3½ fathoms—or 1,500 meshes on the corkline. It is fished during the dark of the moon with the aid of lights.

lantaw-kasig (Tsabakano).—A drift net for catching sardines in Mindanao and Sulu Archipelago. A typical gear measures 14 to 16 by 6 to 8 fathoms. It is usually made of No. 16 cotton sewing thread knitted with a mesh of 1½ inches stretched, and is operated during the dark of the moon with the aid of lights. *Synonym:* Lantaw (Sa. and T. Sug.).

lantay (Sebu Bisaya).—A fish trap in Cotabato Province.

lapak (Ilongo Bisaya).—A fish corral in Negros and Iloilo Provinces.

lapad (Samar Bisaya).—A shallow-water fish corral in Almagro, Samar Province.

largarete (Tagalog-Spanish).—A set gill net of cotton twine for taking sardines. It is hung like a curtain from an anchored banca by two bamboo poles attached fore and aft. The fish entangle themselves on both sides of the net as they approach the light or lights used to attract them.

latule-patule (Pangasinan).—A pole and line in which the pole (latule) is stuck into the mud of river banks. On the free end of the pole a kind of noise-maker (patule) made of a bamboo joint split at one end, is hung to attract the fisherman when the fish bites.

lawag (Samar Bisaya).—A round haul seine for taking pelagic species that run in compact schools. Made of cotton twine, it is operated from two boats with the aid of powerful petroleum lamps. *Synonyms:* Iwag (Il. Bis.; Sam. Bis.); sapyaw (Pil.); sapyaw-kon-luses (Sam. Bis.-Sp.); kabyaw (Bik.).

lawin (Iloko).—A short set pole and line for catching dalag (murrel) and hito (clariid catfish). It is baited with a live frog or an earthworm and is fished in fresh water. *Synonyms:* Patukba (Tag.); lawing (Ilk.).

lawing (Iloko).—In Sinait, Ilocos Sur Province, a term synonymous to lawin.

lawiswis (Tagalog).—A fish rake of bamboo for catching shrimp by simply scaring them into jumping aboard a tilted banca. It is manipulated by one man in wading depths of rivers. *Synonyms:* Kalaskas (Kap.); kalakay (Tag.-Bik.).

laya (Bisaya; Bikol).—General term for cast net. *Synonyms:* Dala (Tag.); tabukol (Ilk.); sabukol (Pang.); lala (Samb.); ban-ay (Ivat.); ataraya (Tsa.; Seb. Bis.-Sp.).

laya-bintay (Aklan Bisaya).—General term for cast nets in Antique Province.

laya-pamalanak (Samar Bisaya).—A cast net used for catching mullet in Samar Province.

laya-pamasayan (Samar Bisaya).—A cast net used for catching shrimp in Samar Province.

laya-panabangongo (Samar Bisaya).—A deep-water cast net for catching tabangongo (ariid catfish) in Samar Province.

laya-panamban (Sebu Bisaya).—A deep-water cast net for catching tamban (Indian sardine) in Cebu Province. It is fished from a banca.

laya-pangkikiro (Samar Bisaya).—A cast net for taking kikiro (spadefish) in Samar Province.

laya-panilag (Samar Bisaya).—A deep-water cast net common in Barrio Bonoanan, Catbalogan, Samar Province, for catching silag (transparent sardines). From 1½ to 3 fathoms in length, it is fashioned of meshes ½-inch, stretched.

laya-panilot (Sebu Bisaya).—A cast net used in Bohol and Cebu Provinces and in northern Mindanao for taking all kinds of small fish. It is made of very small meshes.

layrong (Ilongo Bisaya).—A barricade of stones and rocks constructed on reefs with two wings and a collecting chamber. It fishes during the receding tide.

legma (Pangasinan).—A simple fish shelter constructed of debris. *Synonyms:* Lima or lama (Pang.); bumbon (Tag.).

lellen (Iloko).—A barricade built in rivers for taking young gobies. It consists of two parallel dams of stones and a bamboo matting terminal wall which leads to the bubo (collecting pot).

leynete (Sebu Bisaya).—A deep-water fish corral found in Zamboanguita, Negros Oriental Province. It is built in waters more than 2½ fathoms deep.

liay (Ilongo Bisaya).—A drive-in-net with a scareline used in Looc, Romblon Province.

libas (Sebu-Bisaya).—General term for lines in Agusan Province.

libot (Bikol Tagalog).—A drag or beach seine used in Camarines Norte and southern Quezon Provinces.

likom-likom (Sebu Bisaya).—A drag seine fished in Bohol and Cebu Provinces.

likos (Ilongo Bisaya).—A beach or drag seine in Bacolod, Negros Occidental Province. Made of sinamay, it measures from 100 to 150 fathoms in length. *Synonym:* Pukot (Tag.).

ligkop (Samar Bisaya).—A submerged reef seine designed and operated for capturing rockfish. Fashioned of wide-meshed abaka netting, it is fished from bancas by keeping the seine constantly submerged and touching bottom. This is done by long bamboo poles with one end attached to the floatline. During the operation, divers keep the gear disentangled from snags. *Synonym:* Pukot-likos-bato (Seb. Bis.).

lilang (Ilongo Bisaya).—A rectangular gill net in the form of a curtain with lead weights but no floats. Operated from an anchored banca, it is sunk to the desired depth by means of two weights attached to the opposite ends of the floatline. It is fished with light. *Synonym:* Largarete (Tag.-Sp.).

lilep (Samar Bisaya).—A bow-and-arrow type of fish spear used by a diver. *Synonym:* Bibedol (Sam. Bis.).

lima Pangasinan).—A simple fish shelter made of debris. *Synonyms:* Legma (Pang.); bumbon (Tag.).

limpot (Tagalog).—A sinamay filter net for catching shrimp in Bulacan Province. *Synonyms:* Dayakos, diyakos, or lumpot (Tag.).

linagkaw (Sebu Bisaya).—A fish corral found in Talibon, Bohol Province.

linati (Ilongo Bisaya).—One of the simplest types of fish corrals found in western Visayas and a forerunner of the more complicated ones now used there. It consists of only one semicircular enclosure, a leader, two diverging wings, and two landing platforms flanking the enclosure. Here the catch is made by the sigin (scoop seine). Its name is derived from "lati" (crescent-shape).

linge (Taw Sug; Samal).—A cotton gill net for catching gars at night, without the aid of light. It is longer than the lantaw (T. Sug.; Sa.), measuring 38 by 1½ fathoms.

linge (Aklan Bisaya).—A drive-in-net operated with a scareline. *Synonyms:* Kulokutok (Tag.); hanig (Bis.).

linge-balo (Tsabakano).—A drift net for catching gars. It is generally made of No. 12 cotton sewing thread knitted with a mesh of 1½ inches, stretched and has no leads or sinkers. This net is fished at night by scaring the fish into the meshes without the aid of light.

linge-pamalanak (Tsabakano).—An encircling gill net for catching mullet by forcing the fish into gilling. It is generally made 120 fathoms long and 42 meshes deep, of No. 16 cotton sewing thread, and knitted with a mesh of 2½ inches, stretched.

lingi (Bisaya).—A small shore or drag seine used in rivers. It is usually fished like a gill net.

linuyot (Samar Bisaya).—A shallow-water fish corral of the inangkla type that is built in water about 1½ fathoms deep. It is designed with two or three cribs on one side of the large semicircular enclosure.

linya (Tagalog-Spanish).—A common type of deep-water fish corral in Manila Bay. It consists of a long leader and a large semicircular enclosure provided with two smaller chambers on one side, the last of which is the collecting crib. *Synonyms:* Paugmad, inangkla, or habug (Sam. Bis.).

liwliw (Iloko).—A pole and line baited with a live frog for catching dalag. This gear is operated with a back-and-forth motion. The term also denotes a pole and line used in sea fishing. *Synonym:* Galay (Tag.).

loy-loy (Sambal).—General term for handlines.

lukayan (Sebu Bisaya).—A sinamay drive-in-net operated with a scareline for catching coral reef species. *Synonyms:* Bahan (Bis.); baling-lukay (Seb. Bis.).

lukob (Bisaya; Maranaw).—A fish corral built near river mouths and fished during receding tide. *Synonyms:* Pahubas (Bis.); pahibas (Tag.).

lukon-lukon (Ilongo Bisaya).—A squid jig shaped like a lukon (prawn) with two series of barbless hooks tied at the "tail" portion. It is fished by jerking the gear as it moves through the water. *Synonyms:* Kawil-pangpusit (Tag.); ulang-ulang (Seb. Bis.; Sa.); hila-hila (Il. Bis.).

lukot-anod-pamarungoy (Sebu Bisaya).—A movable fish corral fished during ebb tide. It has a pair of long wings set parallel to the coastline and flanking the central collecting bag of netting. It is similar to the sabay (Bik.), except that the latter has a collecting portion of split bamboo matting.

lugo (Samal; Maranaw).—A barricade built among reefs of coral and rocky boulders. Fished during receding tide, its collecting device is a bubo (fish pot).

luma (Sambal).—A simple fish shelter made of debris. *Synonym:* Bumbon (Tag.).

lumpot (Tagalog).—A filter net for catching shrimp. *Synonym:* Limpot (Tag.).

Lungga (Tagalog).—A fish trap made of a pile of stones for enticing gobies (especially spawning gobies) and ariid catfish into the hole thus formed. It is fished in various ways.

lun-oy (Bikol).—A troll line fished with natural bait for taking pelagic fish such as flying fish, tuna, swordfish, sailfish, spearfish, and Spanish mackerel.

luob (Ilongo Bisaya).—A sinamay or cotton netting trap net set seaward with a barricade of twigs behind it. Flanked by two wings of split bamboo matting, it is fished by driving the fish shorewards until the barrier is encountered. The fish then land in the net. *Synonym:* Patakiyob (Il. Bis.)—a series of such units set in a definite spot.

luong (Tagalog).—A fish shelter used on the shores of Laguna de Bay for taking dalag. It consists of a hole furnished with enough vegetable debris to make it attractive to prospective egg-laying dalag. The catch is made with a salakab (cover pot) or galay (pole and line).

luyaw (Iloko).—A push net used in Ilocos Sur Province. *Synonym:* Sagap (Ilk.).

M

malamba (Tagalog).—A deep-water fish corral fished during dark nights in Tayabas Bay with the aid of lighted boats. This gear is set about 7 fathoms deep. *Synonym:* Baklad (Tag.).

malawa (Samar Bisaya).—A deep-water set gill net for catching hairtails, milkfish, leather jackets, etc. It is made of abaka twine knitted with a mesh of 6 inches, stretched, and measures 70 to 150 by 3½ to 5 fathoms. It is buoyed up on the corkline by bolobitoon (*Barringtonia asiatica*) floats; but instead of lead sinkers on the bottom line, two stone weights are used for anchoring.

mamuno (Ivatan).—A fish spear or spear gun for catching coral reef fish and octopus. Literally, the term means the act of spearing. *Synonyms:* Panibat or pana (Tag.).

mamurak (Iloko).—A fish shelter built of debris. The catch is made by surrounding the fish with split bamboo matting. The term actually refers more to the accessory matting than to the shelter itself.

manarop-alamang (Pangasinan).—A triangularly-framed sinamay push net for catching small shrimp. *Synonym:* Sakag (Tag.).

manoay-ivoya (Ivatan).—A push net. *Synonyms:* Sakag (Tag.); manoay-masin (Ivat.).

manoay-masin (Ivatan).—A push net. *Synonyms:* Sakag (Tag.); manoay-ivoya (Ivat.).

medya (Bisaya-Spanish).—A fish corral in Samar Province set in waters of moderate depth. These are between the deep-water paugmad (Sam. Bis.), and the shallow-water babhas (Sam. Bis.) in size. *Synonyms:* Pang-alang-alang (Sam. Bis; Mar.); baklad (Tag.; Samb.; Kap.).

minata (Sebu Bisaya).—A fish trap for catching bangos fry migrating inland during high tide. Set near river mouths, it is made with two wings of split bamboo matting and a hammocklike collecting portion of sinamay. *Synonym:* Saplad (Tag.).

moro-bahan (Sebu Bisaya).—A drive-in-net. In this operation, spear fishermen augment the catch by spearing the larger fish enclosed by the scareline.

moro-pangaling (Sebu Bisaya).—A fish pot used in Bohol Province. *Synonym:* Bubo (Pil.).

muro-ami (Pilipino-Hapones).—A drive-in-net in the form of a movable, cotton netting trap net used chiefly for caesios and surgeon fish. The net, consisting of a bag flanked by two long wings, is set among reefs in water from 3 to 10 fathoms deep with the mouth facing the current. Eight fishermen, each with a pendant (buoyed scareline), drive the fish into a bag. The catch is then brailed out. *Synonym:* Sinsoro-hapones (Pil.-Sp.).

N

nanaw (Bisaya).—A fish spear used with a torchlight.

nasa (Iloko; Tsabakano).—A bamboo fish pot used in northern Luzon for catching crabs. In Zamboanga, the word means a somewhat cylindrical bamboo fish pot, the ends of which have openings guarded by nonreturn valves. *Synonyms:* Bubo (Pil.); tapangan (Tag.).

natural (Bisaya-Spanish).—Gill nets used in Cebu Province for catching flying fish. Of two kinds, the smaller is operated by one man and is made 7 by 2 fathoms, usually of No. 40 sewing thread with a mesh 1½ inches, stretched. The larger is composed of ten 3½-fathom pieces joined as a unit. Two boats are used in setting the net across the current, then fishermen aboard five other boats drive the fish into gilling by making all sorts of noise and throwing stones. *Synonyms:* Panirikinya (Seb. Bis.); pamangsi (Seb. Bis.).

natural (Bikol-Spanish).—A simple type of shallow-water fish corral found in San Miguel Bay and Ragay Gulf. It is composed of a leader flanked by two wings and two heart-shaped enclosures which terminate in a collecting pound from which the fish are brailed out. *Synonyms:* Ordinaryo, alas-na-kupas, natural (Bik.-Sp.); pamasayan (Bik.)—used in San Miguel Bay chiefly for taking shrimp.

noh (Samal).—A fish spear used in torch fishing in wading depths.

O

odaod (Iloko).—A lift net for taking birot (sleeper).

ordinaryo (Bikol-Spanish).—A shallow-water fish corral. *Synonyms:* Natural or pamasayan (Bik.-Sp.).

osok (Sebu Bisaya).—A common type of fish shelter found in Alegria, Cebu Province. It is fashioned of an anchored bamboo pole to which coconut leaves are attached for luring fish into seeking refuge. The catch is effected with a basnig-like bag net.

P

paabong (Samar Bisaya).—A set gill net for catching gizzard shad in Samar Province. It measures 50 by 70 by 20 feet and is knitted of abaka twine with a mesh of 2 inches, stretched. Set between two bancas, it is devoid of corkline floats and bottomline leads and is weighted by two stone sinkers.

paadag (Iloko).—A short set pole and line for catching dalag. Usually baited with a live frog, it is stuck into the ground in rice fields and left for some time. *Synonym:* Bantak-igid (Ilk.).

paandap (Iloko).—A cast net for catching shrimp. The fish are first attracted by light in order to concentrate them in shallow water near shore, where the net is used. The term also refers to the act of scaring fish into sounding by beating the water surface with split bamboos, or by employing a scareline. The fish which sound as a result of the disturbance are picked up from the bottom by hand.

paanod (Bisaya; Tagalog).—A set gill net for catching sardines. It is generally made of No. 40 sewing thread knitted with a mesh from ½-inch (paanod-malimit), to ¾-inch (paanod-malaki), stretched, and trailed from the stern of an anchored banca. Light is used to attract the sardines into gilling. The term is somewhat a misnomer, for "anod" denotes drifting; and though the net may swing with the current, it never drifts, since the banca is anchored. *Synonym:* Panglawlaw (Tag.).

paayas (Iloko).—A barricade for taking ipon in swift-flowing streams. It consists of a series of stone dams about 1 by 1 by 45 feet, running parallel to the course of the river. A pair of these barriers is provided with a V-shaped trap at the apex of which bubos (fish pots), with mouths facing downstream, serve as the collecting portions to take fish migrating upstream.

pabahaan (Aklan Bisaya).—A fish corral that fishes during receding tide. *Synonym:* Pahubas (Bis.).

pabahay (Tagalog).—A deep-water fish corral used in Paete, Laguna Province, for catching kanduli (ariid catfish). It consists of a leader, a semi-circular enclosure not flanked by wings, and two heart-shaped enclosures on each side leading into the collecting cribs.

pabhas (Bisaya).—A shallow-water fish corral that fishes during receding tide. *Synonyms:* Pahibas (Tag.); sabay and bugkat (Bik.).

pabhas-de-salap (Bikol-Spanish).—A sinamay filter net fished in the same manner as the pabhas, except that woven abaka cloth instead of split bamboo matting is used for filtering the catch.

pakaladkad (Tagalog).—A dredge net for catching snails in Laguna de Bay. It measures about 20 inches wide and has a collecting portion of coarse cotton netting. *Synonyms:* Kaladkad and kaladkad-ng-suso (Tag.).

pakaralet (Tagalog).—A shallow-water fish corral for catching dalag in Paete, Laguna Province. Designed without the conventional wings, it is made with a long leader and one large semicircular enclosure where two collecting cribs, in the form of an apron, are set side-by-side near the nonreturn valve. *Synonym:* Saklitan (Tag.).

pakpak (Pangasinan).—A cotton twine encircling gill net for taking sardines.

pakpet (Pangasinan).—A fish shelter used in the Mangabol fisheries. It consists of piles of debris from which the catch is made by various means. *Synonym:* Bumbon (Tag.).

paktad (Sebu Bisaya).—The pahubas type of fish corral used in Carcar, Cebu Province. It is a shallow-water fish weir that is fished during receding tide.

paktang (Tagalog).—A fish corral found in Bataan Province.

pakulod (Iloko).—A filter net for catching bangos fry and ipon (young gobies). It consists of two diverging wings of staked split bamboo matting which lead into the hammocklike collecting portion of sinamay. *Synonym:* Saplad (Pil.).

padait (Iloko).—A barricade for catching ipon (young gobies) in shallow rivers such as the Amburayan and Laoag Rivers in northern Luzon. Bubos (fish pots) and pataya (hoop nets) are the collecting devices. *Synonyms:* Pamobuan or pingi (Ilk.).

padal (Ibanag).—Fish pots used in Cagayan Province. *Synonym:* Bubo (Pil.).

padaldal (Iloko).—A barricade of staked split bamboo matting for directing fish, especially mullet, to a certain area. The catch is made with a cast net.

padapoan (Bikol).—A fish shelter in Camarines Norte Province which consists of an anchored pile or piles of debris. The catch is effected by various means. *Synonym:* Bumbon (Tag.).

padarisdis (Iloko).—A drive-in-net in Santa Lucia, Ilocos Sur Province, that is operated with a scareline.

padlas (Samar Bisaya).—A set gill net in southwestern Samar, 14 by 14 fathoms, that is operated between two bancas. Before being payed out, the net is immersed in crushed shrimp, and then it is weighted with two anchors. *Synonyms:* Badlas, padumog, pamungbong, pukot-padlas, pukot-padumog (Seb. Bis.).

padlas-panglambiyaw (Samar Bisaya).—A gill net of the padlas type for catching lambiyaw (yellow-lined crevalle).

padugmon (Aklan Bisaya).—A fish shelter. Literally, the term refers to the act of luring fish to a dugmon (shelter). *Synonyms:* Bumbon (Tag.); parugmon (Ban. Bis.).

padumog (Sebu Bisaya).—A gill net in Alegria, Cebu Province, that is baited with crushed shrimp before being payed out. *Synonyms:* Padlas (Sam. Bis.); pamungbog, pukot-padlas, or pukot-padumog (Seb. Bis.).

padusmog (Sebu Bisaya).—A drag or beach seine used in Bantayan, Cebu Province. *Synonym:* Panalibot (Seb. Bis.).

paduyan (Bisaya).—A blanket net for catching shore species. It measures from 5 to 10 fathoms square and is generally made of No. 20 sewing thread. The net is buoyed up on one side by a staked, one-piece bamboo float, and sunk on the other side by lead or stone weights. Men on a banca hold it in a slanting position by pull ropes and lift the gear when fish have been attracted over it. *Synonyms:* Garong (Seb. Bis.); kabyaw (Sam. Bis.).

paed (Iloko).—A series of V-shaped barricades built across swiftly-flowing, gravelly streams for catching ipon (gobies). The fish are guided by canals, fences, or barricades into gates at the apex, where they are caught in sinamay hoop nets.

pagataw (Samar Bisaya).—A two-pronged fish spear for catching various large species. It is operated from a banca during the dark of the moon with the aid of a light.

pagawid (Aklan Bisaya).—A longline used in Panay Island. *Synonym:* Kitang (Tag.).

pagbabahaan (Samar Bisaya).—A rock barricade used in Basey, Samar Province, for catching reef species during ebbtide. It is constructed on reefs along the shores. *Synonym:* Pailigan (Sam. Bis.).

pagsamban (Iloko).—A river barricade in Aringay, La Union Province, for catching mullet, theraponids, bangos, etc. It consists of a semicircular dam of rocks and mud flanked by scarelines. From a stand on one side a cast net fisherman watches for the fish and effects capture with a net.

paguloy (Sambal).—General term for troll lines.

paguyod (Samar Bisaya; Iloko).—A troll line. The term means to pull or to tow. *Synonyms:* Subid-subid (Bis.); pahila or sibid-sibid (Tag.).

pahabog (Bisaya).—A cast net. *Synonyms:* Dala (Tag.); laya (Bis.); lala (Pang.; Samb.).

pahanong (Sebu Bisaya).—A fish shelter made of piles of debris for luring the fish. The catch is made in various ways. *Synonym:* Bumbon (Tag.).

pahibas (Tagalog).—A shallow-water fish corral that fishes during receding tide. *Synonyms:* Pahubas (Bis.); pabhas or bugkat (Sam. Bis.).

pahila (Tagalog; Aklan Bisaya).—A troll line used in Batangas Province. "Hila" means to pull or to tow. *Synonyms:* Sibid-sibid (Tag.); subid-subid (Seb. Bis.).

pahinas (Aklan Bisaya).—Troll lines. *Synonyms:* Sibid-sibid (Tag.); subid-subid (Seb. Bis.); paguyod (Sam. Bis.).

pahubas (Bisaya).—A shallow-water fish corral that fishes during receding tide. "Hubas" means ebbtide. *Synonyms:* Pahibas (Tag.); pabhas or babhas (Bis.).

pahubas-inangkla (Samar Bisaya).—A shallow-water fish corral fished during receding tide in Basey, Samar Province. It is of the inangkla (anchorlike) type.

pahunas (Aklan Bisaya).—A rock barricade built on reefs near shore for catching coral reef species during receding water. The term also refers to a shallow-water fish corral that also fishes during receding tide.

pahunas (Bisaya).—A shallow-water fish corral that fishes during receding tide. *Synonyms:* Pahubas (Bis.); pahibas (Tag.).

pahunas-inangkla (Samar Bisaya).—An anchorlike shallow-water fish corral that fishes during receding tide. *Synonym:* Pahubas-inangkla (Sam. Bis.).

pahutik (Samar Bisaya).—A shallow-water fish corral that fishes during receding tide. It is designed with a long leader, two short wings converging into two heart-shaped enclosures, and a terminal collecting pound from which the catch is brailed out. *Synonym:* Tinures-pahubas (Sam. Bis.).

pailig (Bisaya).—A series of short gill nets staked across rivers to take small mullet, halfbeaks, etc., which enter rivers during high tide and go downstream during ebb. Each net measures 15 feet square and is generally made of Nos. 20 or 40 cotton thread knitted with a mesh of 2 inches, stretched.

pailig (Aklan Bisaya).—A stone barricade for catching reef species during ebb tide. Built on reefs near shore, it catches fish migrating back to deep waters.

pailigan (Samar Bisaya).—A stone or rock barricade that fishes during receding tide. Built on reefs along the shore, it is made with openings or gates of some form of textile or non-textile device for filtering the catch. *Synonym:* Pagbabahaan (Sam. Bis.).

palaan (Bisaya).—A deep-water fish corral used in Capiz and Romblon Provinces. *Synonym:* Payaan (Ak. Bis.).

palaan-bulonan (Aklan Bisaya).—A deep-water fish corral of the inangkla (anchor-shaped) type.

palaan-tulis (Aklan Bisaya).—A shallow-water fish corral found in Makato, Capiz Province. It consists of a leader and two wings converging into successive, somewhat triangular, chambers, as in the tulis or pangalato type. The latter terminate in a circular collecting crib.

palabo (Sebu Bisaya).—A deep-water fish corral in Ubay, Bohol Province.

palabay (Sebu Bisaya).—An encircling gill net in Santander, Cebu Province. *Synonym:* Kayagkag (Bis.).

palakad (Aklan Bisaya).—A push net. *Synonym:* Sakag (Tag.).

palagod (Sebu Bisaya).—A fish corral, 15 or more feet deep, in Bohol Province.

palamag (Iloko).—A fish shelter for luring shrimp and gobies. It is made of piles of debris. *Synonyms:* Bumbon (Tag.); arong (Sam. Bis.); rama (Ilk.).

palanaan (Samar Bisaya).—A fish pot. *Synonyms:* Panggal (Bis.); panak (Bis.; Kuy.).

palanaan-balawis (Sebu Bisaya).—A fish pot used in Siquijor, Negros Oriental Province.

palangre (Sebu Bisaya-Spanish).—General term for longlines. *Synonyms:* Kitang (Tag.); labay (Bis.).

palangre-de-moro (Sebu Bisaya-Spanish).—A troll line used in Calape, Bohol Province.

palaoy (Iloko).—General term for drop lines or ordinary handlines.

palapad (Tagalog; Kapampangan).—A shallow-water fish corral. In some instances it is a simple movable enclosure of bamboo matting that fishes during receding tide. In Tayabas Province this corral is generally less than 9 feet deep. *Synonym:* Palapad-baklad (Tag.).

palapad-baklad (Tagalog).—A shallow-water fish corral in San Jose, Mindoro Province, that fishes during receding tide. *Synonym:* Palapad (Tag.).

palapad-lambat (Tagalog).—A staked trap net set in tidal flats and fished during receding tide. It is similar to the palapad in every aspect of its operation, except that netting is used instead of bamboo matting.

palaway (Tagalog).—A set longline for catching dalag. The mainline is tied to stakes to keep it above the water surface. To this are attached short, snooded hooks baited with live frogs. It is fished by keeping the live bait near the surface. *Synonyms:* Patukba or paluay (Tag.).

palayaw (Iloko).—A river barricade for ipon (goby fry), similar to the pataya (Ilk.). A staked barricade of cotton cloth produces a swift flow in the river, thus frightening the gobies into retreating. They are then led into a parallel series of banana sheath barricades which guides them into fish pots set at the open end of the latter barriers.

palayaw-ambulante (Iloko-Spanish).—A movable barricade of the palayaw type used in Tagudin, Ilocos Sur Province, for catching leaping fish, such as small mullet.

palayaw-puwesto (Iloko-Spanish).—A set barricade of the pataya type for taking gobies in swiftly flowing streams.

palaylay (Pangasinan).—A drag seine similar to the karukod (Ilk.), operated with one wing payed out somewhat more offshore than the other. *Synonym:* Parayray (Pang.).

pal-eg (Iloko).—A bamboo tube for attracting gobies. Open at each end, it is sunk in rivers, left for some time, and hauled in while simultaneously closing the ends with the hands.

palhag (Aklan Bisaya).—A river fish corral consisting of two wings flanking a central collecting pound or crib. It is devoid of a leader. *Synonym:* Bunuhan (Tag.).

palibong (Tagalog).—A fish corral built in rivers, brooks, and swamps of Lopez, Tayabas Province. It is similar to the bunuhan (Tag.).

palibtok (Iloko).—A barricade for catching ipon (young gobies) in the rivers of northern Luzon. *Synonyms:* Burayok or pamalibtokan (Ilk.).

paliwliw (Iloko).—A set pole and line for catching dalag in Sinait, Ilocos Sur Province. It is simply a short pole stuck into the ground and the hook baited with a live frog. It is similar to the patukba (Tag.).

palned (Iloko).—A gill net for sardines in northern Luzon. Generally it is 25 by 3 fathoms, with a mesh of ½- to 1-inch, stretched. The net is payed out in an arc, with the boat covering the open portion, while the fishermen make as much noise as possible and drive the fish into gilling. Similar to, but much smaller than the pang-lambang (Tag.), this gear is operated with several units working simultaneously.

paloay (Iloko).—A longline used in Paniqui, Tarlac Province. *Synonyms:* Kitang (Tag.; Pang.; Ilk.; Samb.); palaway (Tag.).

palseb (Iloko).—A set pole and line for catching dalag. The hook is baited with live hito (clariid catfish) and biya (goby) and made to fish on the bottom. The short pole serves merely as an anchorage, rather than an attachment for the line.

palsiit (Iloko).—A set pole and line for catching dalag. The hook is baited with an earthworm, and the line dangles from the pliable tip of the tapering pole. *Synonym:* Paluway (Tag.).

paluay (Tagalog).—A longline for catching dalag. It is baited with live frogs and is similar to the paloay (Ilk.). *Synonym:* Palaway (Tag.).

palubo (Pangasinan).—A triangularly framed drive-in-net operated with a scare-line in Pangasinan Province. *Synonyms:* Konay or solambaw (Sam. Bis.).

palubog (Bikol; Samar Bisaya).—An encircling gill net of cotton netting that is similar in construction, design, and operation to the bating (Tag.), but is much smaller. *Synonym:* Patalang (Bik.).

palubog-mayor (Bikol-Spanish).—A large encircling gill net for catching sardines. *Synonym:* Palubog-sa-tamban (Bik.).

palubog-minor (Bikol-Spanish).—An encircling gill net, much smaller than the palubog-mayor (Bik.-Sp.), used for catching sardines.

palubog-pangkiskisan (Bikol).—An encircling gill net for catching kiskisan (spotted grunt) in Sipocot, Camarines Sur Province. *Synonym:* Palubog-sa-kiskisan (Bik.).

palubog-sa-balanak (Bikol).—An encircling gill net for catching balanak (mullet) in San Miguel Bay. It is generally made of No. 40 cotton sewing thread knitted with a mesh of 1½ inches, stretched.

palubog-sa-kabasi (Bikol).—An encircling gill net for taking kabasi (short-finned gizzard shad) in San Miguel Bay. Usually it is made of No. 20/9 cotton twine knitted with a mesh of 2 inches, stretched.

palubog-sa-kiskisan (Bikol).—An encircling gill net for catching kiskisan (spotted grunt) in San Miguel Bay. Usually it is made of Nos. 20/6 or 20/9 cotton twine knitted with a mesh of 4 inches, stretched. *Synonym:* Palubog-pang-kiskisan (Bik.).

palubog-sa-lawihan (Bikol).—An encircling gill net for taking lawihan (long-finned gizzard shad) in San Miguel Bay. It is generally made of No. 30/4 cotton twine knitted with a mesh of 2 inches, stretched.

palubog-sa-tabangongo (Bikol).—An encircling gill net used for tabangongo (ariid catfish) in San Miguel Bay. Ordinarily it is made of No. 30/4 cotton twine knitted with a mesh of 4 inches, stretched.

palubog-sa-tamban (Bikol).—An encircling gill net for taking tamban kabasi-on (Bik.) or lapad (Tag.; deep-bodied sardine) in San Miguel Bay. *Synonym:* Palubog-mayor (Bik.-Sp.).

palukso (Tagalog).—A fish corral for catching dalag that is operated in creeks or rivers near Laguna de Bay when water in the lake is receding. It consists of two wings converging into a heart-shaped enclosure, a platform on which the dalag land, and a live-box beside the latter. *Synonyms:* Balingad-ngad or paluksohan (Tag.).

palukso (Sebu Bisaya).—A set trap net of sinamay or cotton netting. Flanked by two wings of split-bamboo matting, it is set seaward and has barricades of twigs behind it. *Synonyms:* Luob or patakiyob (Il. Bis.).

palukso (Pangasinan).—A fish trap for catching dalag. It is operated like a barricade in rivers, creeks, or openings of rice-field dikes when the water is being drained. It is fashioned of slanting, V-shaped split-bamboo matting into which the dalag leap.

paluksohan (Sebu Bisaya).—A barricade with two winglike dams converging from upstream into a split-bamboo matting platform, where fish, migrating to the sea, are caught. *Synonym:* Bisig (Seb. Bis.).

paluksohan (Tagalog).—A fish corral operated in creeks and rivers near Laguna de Bay for taking dalag. It has a landing platform and is usually fished when water in the lake begins to recede. *Synonym:* Palukso (Tag.).

palumpat (Ilongo Bisaya).—A long fish rake used in rivers of Capiz during the night for catching mullet and shrimp. It is operated by a fisherman from one side of a banca where a landing platform of split bamboo is built. *Synonym:* Lawiswis (Tag.).

paluob (Tagalog).—A small, low, and somewhat circular set enclosure for catching dalag in quiet, shallow coves of inland water. Made of split-bamboo stakes, it is provided with a trap door. *Synonym:* Pataob (Tag.).

palurop (Sebu Bisaya).—A tuck seine of sinamay (abaka cloth). *Synonyms:* Baling-sa-laod or baling-lawod (Seb. Bis.).

palutaw (Sebu Bisaya).—A series of individual drop lines for catching bangsi (flying fish). Each line is about 9 feet long and is buoyed by a subcylindrical wooden float. Operated somewhat like the longline, the gear is left unattended for some time. *Synonym:* Pamataw (Seb. Bis.).

paluway (Tagalog).—A set pole and line for catching dalag from the surface, intermediate depths, or at the bottom. It is generally baited with a live frog, earthworm, clariid catfish, or goby. *Synonyms:* Bantak, palsiit, or palseb (Ilk.).

paluyot (Sebu Bisaya).—A fish corral found in Bohol Province.

pamalanak (Pangasinan).—A rectangular drive-in-net operated with a scareline for catching banak (mullet) in Bolinao, Pangasinan Province.

pamalangsi-likos (Sebu Bisaya).—A drag seine for bangsi (flying fish) in Boljoon, Cebu Province.

pamalaw (Bikol).—A two-man drag seine for catching balaw (tiny shrimp). Made of sinamay, it is equipped with a pocket measuring 10 to 15 feet, and wings 10 to 15 by 3 feet. *Synonym:* Sarap-sa-balaw (Bik.).

pamalibtokan (Iloko).—A river barricade in northern Luzon for catching ipon (young gobies). It is fashioned of two V-shaped dams flanked by dikes set perpendicular to the banks, and other dams and fences running parallel to the course of the river. The gates are guarded by collecting devices, such as fish pots or filter nets. *Synonyms:* Palibtok or burayok (Ilk.).

pamaliling (Sebu Bisaya).—An encircling gill net used in Konda, Cebu Province, for catching sardines. Wooden plungers are employed to scare the fish into gilling. *Synonym:* Pukot-panumbok (Seb. Bis.).

pamaling (Sebu Bisaya).—The act of fishing with the use of the baling (Bis.), a sinamay drag seine designed with a pocket or bag.

pamalo (Sebu Bisaya).—A gill net used in Bohol and Leyte Provinces for catching balo (garfish).

pamalos (Tagalog).—A gaff for catching eels in the muddy bottoms of fishponds. It is fashioned with a horizontal handle or butt and a blade having seven outwardly-curved points and two curved inwards.

pamana (Maranaw; Bisaya).—A fish spear used in Malabang, Lanao Province, and in many places in the Visayas.

pamangkaw (Tagalog).—A long-handled dip net of cotton netting employed in hauling in a baited line, the latter used as an accessory in catching pomfret with the pangduhay (Tag.), a deep-water cast net. *Synonyms:* Tigpaw (Bis.); singgapong (Ilk.).

pamanggal (Sebu Bisaya).—A fish pot. Literally, the term refers to the act of fishing with a panggal (Bis.), a fish pot.

pamangsi (Sebu Bisaya).—A gill net for catching bangsi (flying fish) in Lazi, Negros Oriental Province. *Synonyms:* Panirikinya or natural (Bis.-Sp.).

pamansikol (Sebu Bisaya).—Handlines or drop lines used in Cebu Province.

pamantak (Sebu Bisaya).—A fish pot. Actually, the term refers to the act of fishing with a bantak (Bis.), a cone-shaped bamboo fish pot.

pamarungoy (Sebu Bisaya).—A purse seine for catching barungoy (flying fish) in Cebu and Negros Oriental Provinces. *Synonyms:* Pukot-bangsi or pukot-pamangsi (Seb. Bis.).

pamasayan (Bikol).—A shallow-water fish corral used in San Miguel Bay for catching pasayan (shrimp). *Synonyms:* Natural, ordinaryo, or alas-na-kupas (Bik.-Sp.).

pamataw (Sebu Bisaya).—A series of individually floated drop lines for catching flying fish. These are left unattended for some time. *Synonym:* Palutaw (Seb. Bis.).

pamilis (Iloko).—A set gill net in Caoayan, Ilocos Sur Province, for taking bilis (sardines). *Synonyms:* Palned or sadeng (Ilk.).

pamingwit (Sebu Bisaya).—A general term for lines in Oroqueta, Misamis Occidental Province. Literally, the term refers to the act of fishing with lines.

pamitana (Banton Bisaya).—A handline fished from a banca. Strictly speaking, it refers to the act of handlining.

pamitin (Tagalog).—A modified pole and line in Laguna de Bay for catching dalag. Meat of kuhol (snails) is used for bait during times when live frogs are hard to procure. In the former case, the water is made murky by treading with the feet, in order to keep smaller fish from nibbling on the bait. *Synonym:* Patukba (Tag.).

pamobuan (Iloko).—A barricade of sawali (webbed-bamboo matting) for catching ipon. Placed across shallow rivers, it is designed with or without a center escapement, the collecting devices consisting of a series of large, cylindrical bubos (fish pots). *Synonyms:* Pingi or padait (Ilk.).

pamonit (Aklan Bisaya; Banton Bisaya).—A pole and line. Literally, the term refers to the act of fishing with a bunit (pole and line). *Synonym:* Bunit (Bis.).

pamulanguso (Tagalog).—A deep-water cast net used in Manila Bay for catching pulanguso (immature sardines). As a rule, the net is made of Nos. 40 or 50 linen twine knitted with a mesh of ¾- to ⅝-inch, stretched.

pamulinaw (Tagalog).—A combination shelter-barricade in the sea for taking small mullet, cardinal fish, young bangos, and anchovies in Bataan Province. The catch is made with a cast net.

pamungbong (Sebu Bisaya).—A gill net used in Bohol, Cebu, and Negros Oriental Provinces. Similar to the pukot-padlas and the padumog (Seb. Bis.), it is baited with macerated shrimp.

pamuntonan (Sebu Bisaya).—Handlines or drop lines in Agusan Province. Actually, the term refers to fishing grounds for handlines. *Synonym:* Talunton (Seb. Bis.).

pamuraw (Sebu Bisaya).—A gill net used in Naval, Leyte Province, for catching buraw (striped mackerel).

pamuraw-buraw (Sebu Bisaya).—A purse seine for catching buraw (striped mackerel). *Synonym:* Kubkob (Bis.-Tag.).

pana (Tagalog).—A fish spear of various designs in which the principle of action in each is that of the bow and arrow.

pana (Iloko).—A general term for fish spears in which the principle of action is that of the bow and arrow.

pana (Bisaya Ivatan; Bikol).—A term for fish spear synonymous to pana (Tag.), except that the accent is on the second, instead of the first syllable.

panabit (Kuyonon).—Squid jigs used in Palawan Province.

panabol (Bisaya).—A set gill net.

panak (Kuyonon; Sebu Bisaya).—Small bamboo fish pots. *Synonym:* Panggal (Bis.).

panakab (Sebu Bisaya).—A cover pot. Literally, the term means fishing with a salakab (cover net).

panak-alimango (Kuyonon).—A five-sided, globular bamboo fish pot for catching alimango (land crab). It has a circular opening devoid of a nonreturn valve, and it is baited with coconut meat.

panaklob (Tagalog).—A circularly-framed net used to cover the roof of a pugad-pugad (fish shelter) when catching spawning dalag.

panada (Bikol).—A stone barricade built on reefs near shore for catching rock fish during receding tide. Literally, the term means the act of fishing with the sada (reef barricade).

panadlas (Sebu Bisaya).—A drag or beach seine used in Cebu and Negros Oriental Provinces.

panagap (Tagalog).—Term for a small drag seine which is synonymous to sagap (Tag.), except that it refers more to the act of fishing with a sagap (drag seine).

panagat (Bikol; Aklan Bisaya).—General term for lines, referring usually to handlines or drop lines, in Panay Island and Pandan, Catanduanes Province.

panagat (Kuyonon).—A gill net about 25 fathoms by 3 feet, with meshes ½-inch, stretched. After causing the fish to gill by making as much noise as possible, fishermen haul the net to shore.

panagat (Sebu Bisaya).—A gaff designed with a curved handle or butt for catching eels in the rivers of northern Mindanao.

panalibot (Sebu Bisaya).—A drag or beach seine in Bantayan, Cebu Province. *Synonym:* Padusmog (Seb. Bis.).

panalikop (Batangas Tagalog).—A ring net for catching tuna and bonito in Batangas and Balayan Bays. The purse rings are attached only on or near the bunt or landing piece. *Synonyms:* Panambakol, pukot-pangtulingan (Bat. Tag.).

panalipot (Ilongo Bisaya).—A fish shelter made of piles of stones on reefs. After the fish have been enticed to seek shelter, they are caught by various means or picked up by hand.

panambakol (Batangas Tagalog).—A ring net used in Batangas Province for catching tulingan (tuna), especially tambakol (yellowfin). *Synonyms:* Panalikop or pukot-panulingan (Bat. Tag.).

panamban (Tagalog).—A deep-water cast net used in Manila Bay for catching tamban (adult sardines). It is usually made of Nos. 40 or 50 linen twine knitted with a mesh of 1¾-inch, stretched.

panamban (Sebu Bisaya).—A gill net for catching tamban (sardines) in Ubay, Bohol Province. It may be used with or without light.

panamban-palong-palong (Sebu Bisaya).—A bag net for catching tamban (sardines) in Ubay, Bohol Province. It is operated with the aid of light. *Synonym:* Basnig (Pil.).

panaon (Aklan Bisaya).—A river barricade having fish pots as collecting portions of the trap.

panara (Bikol).—A small encircling gill net used for catching sardines in Jose Panganiban, Camarines Norte Province. *Synonym:* Panki (Bik.).

panarukoy (Iloko).—A gill net for catching tarukoy (fiddler crabs).

panaruyan (Ivatan).—A pole and line.

panalawasig (Sebu Bisaya).—A gill net for catching salawasig (halfbeaks).

panki (Bikol).—A small encircling gill net for catching sardines in San Miguel and Sorsogon Bays, and Masbate Province. In Lake Buhi, Camarines Sur Province, this term refers to a drag seine of wide mesh used for catching carp in the middle or deeper water. *Synonym:* Panara (Bik.).

pandomuot (Sebu Bisaya).—A fish corral found in Dinagat, Surigao Province.

panera (Bisaya-Spanish).—A small fish corral used in Zamboanga. Designed with or without wings, and having one or two heart-shaped chambers, it is set at river mouths, creeks, or across fishpond gates to capture fish as the water recedes.

panga (Aklan Bisaya).—A hook for catching alimango (land crabs) inside their burrows. It is made with a curved, blunt blade attached to the tip of a wooden or bamboo handle, and is similar to panukot (Tag.).

pangabasi (Iloko; Bikol; Kapampangan; Bisaya).—A gill net for catching kabasi (gizzard shad).

pangaber (Iloko).—A set gill net used in the Iloko provinces for catching aber (deep-bodied sardine). *Synonyms:* Palned, sadeng, pang-aber (Ilk.).

pang-aber (Iloko).—A set gill net for taking aber (deep-bodied sardine) in the Iloko provinces. *Synonyms:* Pangaber, palned, sadeng (Ilk.).

pang-agwas (Sebu Bisaya).—A gill net for catching agwas (large mullet).

pangahig (Tagalog).—A term for either a rake or a cotton netting dredge net used in Laguna de Bay, Pasig River, and other places in the Tagalog region for collecting ark shells and snails. The rake is made with a long bamboo handle and a wire netting bag, and it is operated by one man from a banca.

pangal (Maranaw).—A small, basketlike, globular fish pot for catching all kinds of bottom fish as well as crabs, large prawns, and lobsters. Made of rattan or bamboo, it has a circular opening on top devoid of a nonreturn valve, but it is provided with a short, collarlike projection.

pang-alang-alang (Bisaya; Maranaw).—A fish corral of moderate depth, generally less than 2½ fathoms, with the design of a paugmad (Bis.). It has a leader and a large, semicircular enclosure, but is devoid of wings and collecting pound. *Synonym*: Medya (Sam. Bis.).

pang-alangan (Tagalog).—A deep-water cast net used in Manila Bay for catching alangan (medium-sized sardines). It is usually made of Nos. 40 or 50 linen twine knitted with a mesh from ⅞- to ¹⁵⁄₁₆-inch, stretched.

pang-alimasag (Tagalog).—A drift net used in Navotas, Rizal Province, for catching alimasag (swimming crab). *Synonym:* Panti (Pil.).

pangaling (Aklan Bisaya).—A drive-in-net, similar to the surambaw (Sam. Bis.) and the katigbi (Tag.), which is operated with a scareline.

pang-aliso (Iloko).—A gill net used in Ilocos Sur Province for catching aliso (gray snapper).

pang-apta (Batangas Tagalog).—A small push net used in Lake Taal for catching apta (small shrimp belonging to the family Atyiidae). It is usually made of sinamay.

pangasag (Aklan Bisaya).—A two-pronged fish spear employed in river fishing for kasag (swimming crab). Literally, the term refers to the act of fishing for this particular kind of crab.

pang-asohos (Tagalog).—A submerged set gill net used in Manila Bay for catching asuhos (whiting or sillago). It is similar to panghoya (Tag.).

pangaw (Sebu Bisaya).—A large, somewhat cubical fish pot used in deep water. *Synonym:* Bubo (Tag.).

pang-awa (Samar Bisaya; Iloko).—A gill net fished in Leyte and Ilocos Provinces for awa (spawning bangos).

pangawil (Tagalog; Aklan Bisaya).—Handlines or drop lines (kawil) operated in deep water from a boat. It is also a term for line fishing in general.

pangay (Aklan Bisaya).—A small, globular baited fish pot for catching fish, crab, shrimp, prawns, and lobsters. It is designed with a circular opening at the top; but has no true nonreturn valve. *Synonym:* Panggal (Bis.).

pangbakoko (Tagalog).—A gill net used in Cavite Province for catching bakoko (large porgies and grunts). In Bataan Province, the term refers to a type of cast net used with a bumbon (fish shelter—a conelike pile of bamboo or wooden posts). The Cavite gear is similar to panti-pangbakoko, while the Bataan device resembles dala-pangbakoko.

pangdomudot (Sebu Bisaya).—A fish corral used in Surigao Province for catching dumodot (anchovies). It is set in from 2 to 6 fathoms of water and is similar in design to the inangkla (Bis.).

pangdugarog (Tagalog).—An encircling gill net fished in Pilar, Bataan Province, for bikaw (threadfins) and pagatpat (young gizzard shad). It is usually made of No. 40 sewing thread knitted with a mesh of 1¼-inch, stretched.

pangduhay (Tagalog).—A deep-water cast net used in Manila Bay for catching duhay (pomfrets). It is generally made of China grass twine knitted with a mesh of 3 inches, stretched. The outstanding feature of this gear is the opening at the apex from which the baited line, used in attracting pomfrets, is retrieved after the fish have been impounded under the net.

pangdulis (Batangas Tagalog).—A drag seine of sinamay for catching dulis (anchovies). *Synonym:* Sagap (Bat. Tag.).

pangdulong (Tagalog).—A fish trap used in Laguna de Bay for catching dulong (gobies). The leader, or guiding barrier, leads the dulong to a floating raft, from under which they are dipped out with a skimming net.

panggal (Bisaya).—A basketlike, globular pot for taking crabs and large shrimp. It has a circular opening on top but no nonreturn valve. *Synonyms:* Pangal (Mar.); panak (Kuy.; Seb. Bis.); pangay (Ak. Bis.).

panggalato (Samar Bisaya; Bikol).—A shallow-water fish corral made with a leader and two wings converging into a large, somewhat angular enclosure, which leads into a collecting crib. *Synonyms:* Dinumpil or dinongpil (Sam. Bis.).

panggalatok (Palanan).—The pangalato type of fish corral used in Casiguran, Quezon Province. Its distinctive feature is that it has angular enclosures instead of the common semicircular chambers.

panggay (Aklan Bisaya).—A small, basketlike, globular fish pot for catching crabs and large shrimp. It is made with a circular opening on top but no nonreturn valve.

panggilid (Tagalog).—A small purse seine used in Cavite Province for fishing near the coast. *Synonym:* Talakop-sa-gilid (Tag.).

panggutob (Sebu Bisaya).—Handlines used in Cebu Province and northern Mindanao for caching gutob (short-bodied mackerel).

panghalubaybay (Tagalog).—A deep-water cast net used in Manila Bay for catching halubaybay (deep-bodied sardine). It is generally made of Nos. 40 or 50 linen twine knitted with a mesh of 1-inch, stretched.

panghaol-haol (Sebu Bisaya).—A gill net used in Merida, Leyte Province, for catching haol-haol (sardines).

panghasa-hasa (Tagalog).—A ring net operated with one or two boats for catching hasa-hasa (short-bodied mackerel). If one boat is used, the term is synonymous to kubkob; if two boats are used, then it means the same as talakop. Recently, this gear was used as a stop seine in Manila and San Miguel Bays for catching bungoan (smooth-headed ariid catfish) and bambangin (flame-colored snapper).

panghilot (Bukidnon).—A snare for catching anga (goby) in the interior of Misamis Oriental Province. It consists of a small noose of fine but stiff abaka fiber tied to the tip of a 4-foot bamboo pole.

panghipon (Tagalog).—A fish corral used in Manila Bay for catching hipon (shrimp). It is constructed in waters from 3 to 6 feet deep.

panghoya (Tagalog).—A submerged set gill net in Manila Bay for catching hoya (large-sized demersal species such as croakers, grunts, nemipterids, large-sized slipmouths).

pang-igat (Tagalog).—A gaff for catching igat (eels). It is made with a curved blade which has a hooklike point at its tip, and a curved bamboo handle for probing mud in drained fishponds.

pang-ilak (Sebu Bisaya).—A bow-gun fish spear for catching ilak (rudder fish).

pang-ilaw (Tagalog).—A push net used in Cavite Province for catching shrimp during the dark of the moon with the aid of light. Literally, the term means fishing with light.

pang-isan (Sebu Bisaya).—A type of line in Konda, Cebu Province.

panglambang (Tagalog).—An encircling gill net for catching sardines that is operated only in the daytime. It is generally made of No. 40/4 cotton twine knitted with a mesh of 1-inch, stretched. One or two boats may be used in its operation. It is similar to the bating (Tag.), except that its meshes run vertically instead of horizontally in relation to the cork and bottom lines.

pangalamok (Tagalog).—A deep-water cast net for catching sardine fry in Manila Bay. It is usually made of Nos. 40 or 50 linen twine knitted with a mesh of ½-inch, stretched.

panglawlaw (Tagalog).—A set gill net for catching sardines in Manila Bay, especially Cavite Province. It is fished during the dark of the moon from the bow of an anchored banca with the aid of a petroleum lamp. *Synonym:* Paanod (Bis.; Tag.).

panglinte (Bisaya).—A fish spear usually consisting of a single-barbed, arrowlike, metal blade shot through a bamboo tube or through an iron pipe by means of rubber bands or elastic by diver-fishermen. *Synonym:* Panuyo (Bis.).

pangluob (Tagalog).—An enclosed fish trap for taking nesting dalag. It is made of split bamboo and designed with a trap door controlled by a triggerlike device. In shallow water, it is set or stuck into the ground, but in deep water, it is floated.

panglumayagan (Sebu Bisaya).—A fish spear for catching lumayagan (spiny lobster) with the aid of a light.

panglurop (Bisaya).—A fish spear with bow-and-arrow arrangement employed by divers. Literally, the term means diving.

panglusong (Tagalog).—A set gill net used in Bataan Province for threadfin and leather jackets. It is approximately 30 by 2 fathoms, and it is generally made of abaka twine knitted with a mesh of 3 inches, stretched.

pangmanamsi (Batangas Tagalog).—A sinamay drag seine used in Batangas Province for catching manamsi (sardine fry). *Synonym:* Sagap (Bat. Tag.).

pangorita (Iloko).—A fish spear used in Ilocos Norte Province for catching korita (octopus) with or without the use of a raft.

pangsanga (Sebu Bisaya).—A three-bladed harpoon used in Misamis Oriental Province for catching sanga (devil ray). Two 10-inch barbless iron hooks tied to a 200-foot, ¾-inch, Manila retrieving line serve as gaffed lines which form the accessory landing gear. This harpoon is operated from a heavily built outriggered dugout.

pangsilinyasi (Tagalog).—A deep-water cast net fished in Manila Bay for silinyasi (sardine fingerling). Similar to the panglamok (Tag.), it is usually made of Nos. 40 or 50 linen twine knitted with a mesh of ½-inch, stretched.

pangsulo (Bisaya).—A fish spear employed in wading depths along shores with the aid of light. Literally, the term means fishing with a torchlight.

pangtamban (Bikol).—An encircling gill net for catching tamban (deep-bodied sardines) in San Miguel Bay. Similar to the palubog-mayor and the palubog-tamban (Bik.), it is made with meshes 1¼-inch, stretched.

pangti (Samar Bisaya).—A drift net usually fished not far from shore for catching pelagic crabs. *Synonym:* Panti (Pil.).

pangtrukos (Tagalog).—A tuck seine for catching silinyasi (sardine fingerlings). It is operated during dark nights with a cordon of small boats that drive fish into the net. *Synonym:* Aboy-bating (Bik.).

pangtunsoy (Tagalog).—A deep-water cast net used in Manila Bay for catching tunsoy (adult fimbriated sardines). Similar to the panghalobaybay (Tag.), it is ordinarily made of Nos. 40 to 50 linen twine knitted with a mesh of 1 inch, stretched.

pangtukos (Tagalog).—A tuck seine for catching silinyasi (sardine fingerlings). It is operated during the dark of the moon, aided by a cordon of small driver boats. *Synonyms:* Aboy-bating (Bik.); pangtrukos (Tag.).

pang-ugnat (Tagalog).—A drive-in-net with a submerged scareline for catching gobies, especially talimosak. The landing net may be fashioned like a push net without runners or a simple rectangular drag seine held by two men.

pangulong (Tagalog).—A stop seine used in San Miguel Bay for catching schools of large-sized spotted pomadasids, snappers, and ariid catfish. Similar to the kubkob (Bik.), it consists of an outer curtainlike impounding net of varied sizes and an inner brailing (pursing) net.

pangutob (Sebu Bisaya).—Handlines operated with the aid of light.

panibid (Ilongo Bisaya).—Troll lines in Pilar, Capiz Province. *Synonym:* Sibid-sibid (Tag.).

panilay (Batangas Tagalog).—A simple handline used both in the sea and in inland water bodies such as Laguna de Bay.

panilo (Bikol-Tagalog).—Dip nets used in Camarines Norte Province.

panilot (Sebu Bisaya).—A small movable fish corral in Tagbilaran, Bohol Province. It is made of bamboo or wire matting, and the catch is brailed out of its collecting pound or crib by a dip net.

paniming (Sebu Bisaya).—Either a circular or a four-cornered globular baited fish pot for catching crabs, shrimp, prawns, and small fish. It has a circular opening on top. Literally, the term means fishing with a timing (Bis.), a fish pot. *Synonym:* Kiming (Kuy.).

panindaw (Aklan Bisaya; Ilongo Bisaya).—A crab lift net for catching swimming crabs. It consists of a coarse-meshed square net mounted on a bamboo cross piece. It is baited and sunk in convenient spots, usually in series, and marked by a float.

paningahan (Tagalog).—General term for gill nets. It may also refer to a fishing ground for all types of gill nets.

panintak (Maranaw).—A pole and line used in Lanao Province. Literally, this term refers to fishing with a sintak (Bis.), a pole and line.

panira (Bisaya-Spanish).—A small, shallow, river fish corral that fishes during receding tide. It is made with or without wings and is provided with one or two heart-shaped chambers.

panirikinya (Bisaya-Spanish).—A gill net used in Cebu Province for catching sirikinya (flying fish). *Synonyms:* Natural (Bis.-Sp.); pamangsi (Seb. Bis.).

panlamba (Sebu Bisaya).—A drag seine in Siaton, Negros Oriental Province.

panlukob (Sebu Bisaya).—A set impounding net in Leyte Province that is fished during receding tide. It is similar to the budhi (Seb. Bis.). When split bamboo matting is used in place of a net, this gear becomes a fish corral similar to the pahubas (Bis.).

panti (Pilipino).—Drift nets. At present, many of these are ordinary set gill nets. *Synonyms:* Pangti (Sam. Bis.); pang-alimasag (Tag.).

panti-hila-hila (Tagalog).—A gill net used in Unisan, Tayabas Province, that is operated like a drag seine.

panti-malamba (Tagalog).—A large gill net used in Unisan, Tayabas Province, for deep-water fishing.

panti-panapulok (Tagalog).—A gill net found in Torrijos, Marinduque Province.

panti-pangibas (Tagalog).—A set gill net designed and operated for catching seaward-migrating fish during ebbtide.

panting-anod (Bikol; Tagalog).—A drift net used in Camarines Sur and Marinduque Provinces for catching lumahan (striped mackerel).

panting-lawlaw (Tagalog).—An encircling gill net operated in Cavite Province for taking lawlaw (sardines). In this sense, the term is synonymous to halang or bating (Tag.). It also refers to a set gill net, one end of which is trailed from the bow of an anchored boat, fished with a light, to attract the sardines. In this case, the term is synonymous to paanod and panglawlaw (Tag.).

panting-palipad (Tagalog).—A drift net used in Paete, Laguna Province, and Jalajala, Rizal Province. One banca is used in its operation.

panting-pang-alimasag (Tagalog).—A drift net for catching alimasag (pelagic crabs) in Manila Bay. Measuring 10 fathoms by 3 feet, it is usually made of No. 30/4 cotton twine knitted with a mesh of 4 inches, stretched, and has wooden cylindrical floats and brass ring weights. *Synonym:* Panti-pang-alimasag (Tag.).

panting-pangbanak (Batangas Tagalog).—A gill net for catching banak (mullet) in Batangas Province.

panting-pangkanduli (Tagalog).—An encircling gill net used for catching kanduli (ariid catfish) in Laguna de Bay. Made with a mesh of 2 inches, stretched, it is designed with floats to keep it from sinking in deep water, and with extra netting at the bottom where the kanduli are caught.

panting-pangdalag (Tagalog).—An encircling gill net for catching dalag in Paete, Laguna Province. It is made of heavy twine knitted with wide meshes. *Synonym:* Panting-pukot (Tag.).

panting-pangdangat (Tagalog).—A gill net used in Batangas Province, especially Lake Taal and vicinity, for catching dangat (glass fish), slipmouths, and other small shore and river fish.

panting-panglumahan (Tagalog).—A gill net operated in Batangas Province for lumahan (mackerel) and galunggong (round scad). *Synonym:* Panti-panglumahan (Tag.).

panting-pangmanamsi (Tagalog).—A gill net used in Batangas Province for catching manamsi (round sardines).

panting-pangtagan (Tagalog).—A gill net used for catching tagan (sawfish) in the deepest portion of Laguna de Bay. It is made of heavy twine knitted with a mesh about 18 inches, stretched.

panting-pangtanigi (Tagalog).—A drift net for catching tanigi (Spanish mackerel) in Cavite and Batangas Provinces. It measures 50 by 2 fathoms, and is made of ramie twine knitted with a mesh from 3 to 4 inches, stretched.

panting-pukot (Tagalog).—A drag seine used in the rivers of Laguna and Rizal Provinces for catching dalag (murrel) and hito (clariid catfish). *Synonym:* Panting-pangdalag (Tag.).

panti-pang-alimasag (Tagalog).—A drift net used in Manila Bay for catching alimasag (pelagic crabs). *Synonym:* Panting-pang-alimasag (Tag.).

panti-pangbakoko (Tagalog).—A drift net used in Manila Bay for catching bakoko (porgies, pomadsids, and grunts). It measures 10- by 1-fathom and is generally made of Nos. 20/6 or 30/6 cotton twine knitted with a mesh of 3 to 4 inches, stretched.

panti-panglumahan (Tagalog).—A drift net operated in Manila Bay for catching lumahan (striped mackerel). It is 50 by 2 fathoms and is generally made of No. 30/6 cotton twine knitted with a mesh of 2 inches, stretched. Its bottom line is without sinkers. *Synonym:* Panting-panglumahan (Bat. Tag.).

panti-pangsabalo (Tagalog).—A drift net used in Cavite Province for catching sabalo (spawning bangos). It measures 50 by 2 fathoms and is made of ramie twine knitted with a mesh of 7 inches, stretched. The bottom line is without sinkers.

panti-pangtanigi (Tagalog).—A drift net for catching tanigi (Spanish mackerel) in Rosario, Cavite Province. *Synonym:* Panting-pangtanigi (Tag.).

pantukos (Tagalog).—A tuck seine operated from two boats during the dark of the moon for catching silinyasi (sardine fingerlings). Schools of the fish are driven into the net by a cordon of many smaller boats. *Synonyms:* Aboy-bating (Bik.); pangtrukos (Kab.).

pangtulingan (Batangas Tagalog).—A ring net used for catching tuna and bonito in Batangas Province. *Synonym:* Pukot-pang-araw (Bat. Tag.).

pantunton (Aklan Bisaya).—A handline. *Synonym:* Tunton (Ak. Bis.).

panubidsubid (Sebu Bisaya).—A troll line used in Negros Oriental Province and in northern Mindanao.

panukot (Tagalog).—A hook for taking alimango. It is made with a curve-tipped metal blade and a bamboo handle. When the hook is inserted into the burrow, the crab clings to the blade; then after it has been turned upside down, the animal is retrieved.

panudsod (Sebu Bisaya).—A push net in Loon, Bohol Province.

panugpo (Tagalog).—A fish shelter for attracting young shrimp and bangos fry. It consists of a series of small twig bundles tied to an anchored surface mainline. The catch is effected by a dip net.

panuyo (Bisaya).—Literally, this term refers to fishing with the aid of a torch; however, the fish spear is the most common gear used in this type of operation. *Synonym:* Panglinte (Bis.).

panyambo (Banton Bisaya; Aklan Bisaya).—A troll line. Literally, the term refers to the act of fishing with troll lines or trolling.

parangli (Maranaw-Spanish).—A longline. *Synonyms:* Palangre, parangri, or paranhe (Bis.-Sp.).

parangre (Bisaya-Spanish).—A longline. *Synonyms:* Palangre (Seb. Bis.-Sp.); parangli (Mar.-Sp.); paranhe (Bis.-Sp.); labay (Bis.); kitang (Tag.).

paranhe (Bisaya-Spanish).—A longline. *Synonyms:* Palangre (Seb. Bis.-Sp.); parangli (Mar.-Sp.); parangre (Bis.-Sp.); kitang (Tag.); labay (Bis.).

paranyaki (Pangasinan).—A drift net used in San Fabian, Pangasinan Province, for catching slipmouth and goatfish. It measures 25- by 1-fathom. In other places in this province the term also refers to the lighted boat in a sapyaw outfit.

parayray (Pangasinan).—A beach seine in Bolinao, Pangasinan Province, which is operated with one wing somewhat offshore. In Alaminos and other places in Pangasinan it refers to a type of shallow-water fish corral that fishes during receding tide. In the former case, the term is synonymous to palaylay (Pang.); and in the latter, it is synonymous to pahubas (Bis.).

pareng (Iloko; Ibanag).—A cylindrical rattan fish pot for catching mullet. It is anchored near the bank and is left to drift with the river current. Mullet migrating downstream with the current are caught in the pot. *Synonyms:* Pateng (Ilk.); gangen (Iban.).

parigdig (Pangasinan).—A square lift net, measuring about 2 fathoms on each side, which is operated in rivers by four persons from four outposts. It is fished with or without the use of pulleys or blocks.

paril (Sebu Bisaya).—A fish corral found in Albuquerque, Bohol Province.

parisak (Ibanag).—A dip net used for scooping up fish caught in beach or drag seines. It also may refer to the type of fishing which causes scared fish, especially gobies, to jump into a banca.

parispis (Iloko).—A drive-in-net used in Ilocos Sur and Ilocos Norte Provinces. It is mounted on a triangular frame and operated with a scareline. *Synonym:* Parisris (Ilk.).

parisris (Iloko).—A triangularly framed drive-in-net fished with a scareline. *Synonym:* Parispis (Ilk.).

parukdok (Pangasinan).—A set pole and line for catching dalag and hito (mudfish). Live frogs, earthworms, and fish are used for bait, and the gear is left overnight without attention.

parugmon (Banton Bisaya).—A fish shelter. *Synonyms:* Padugmon (Ak. Bis.); bumbon (Tag.); rugmon (Ban. Bis.).

pasabal (Kapampangan).—A river fish corral. It consists of two wings converging into a heart-shaped collecting pound from which the catch is brailed out by dip nets. *Synonym:* Bunuhan (Tag.).

pasabal (Tagalog).—A fish corral found in Bataan Province. Set in waters about 1 fathom deep, it consists of a leader and two short wings converging into a rather large, heart-shaped enclosure. The latter leads into a smaller forechamber which terminates in a collecting pound. The catch is brailed out by dip nets. *Synonym:* Pasabal-tabi (Tag.).

pasabal-laot (Tagalog).—A deep-water fish corral used in Bataan Province. It has no collecting pound, and the fish are brailed out of its semicircular enclosure by a sigin (scoop seine).

pasabal-tabi (Tagalog).—A shallow-water fish corral constructed near shore. The catch is brailed out of the collecting cribs by dip nets. *Synonym:* Pasabal (Tag.).

pasabang (Iloko).—A huge fish trap constructed in mouths of rivers. It is made of bamboo splits and has a baglike collecting device of sinamay. *Synonym:* Pasbang (Pang.).

pasabing (Iloko; Pangasinan).—General term for fish corrals in Pangasinan and the Iloko provinces. It is a larger and a more complicated affair than the tarek (Ilk.). *Synonyms:* Baklad (Tag.); sagkad (Bik.); bunuan (Bis.); bunsod (Seb. Bis.); pasaging or pasaking (Iban.).

pasabing-duble (Pangasinan-Spanish).—A river fish corral consisting of two diverging wings and two collecting chambers which lead into each other. The terminal compartment forms the collecting crib.

pasabing-ordinaryo (Pangasinan-Spanish).—A common type of shallow-water fish corral in which the catch is brailed out of the collecting pound by dip nets.

pasabing-sa-balanak (Pangasinan).—A fish corral for catching balanak (mullet). Generally set in rivers, this corral is provided with a landing platform. In this type it is usually necessary to drive the fish into the trap.

pasabing-sa-malaga (Pangasinan).—A fish corral for taking malaga (siganids) in Bolinao, Pangasinan Province.

pasabing-sensilyo (Pangasinan-Spanish).—A typical river fish corral similar to pasabing-duble (Ilk.), except that the terminal collecting crib is located on one side of the semicircular antechamber.

pasaki (Sebu Bisaya).—A river fish corral used in northern Mindanao for catching migratory fish, such as large cavallas, mullet, eels, and grunts, as they migrate seaward from the lakes.

pasaking (Ibanag).—General term for fish corrals. *Synonyms:* Pasabing (Ilk.); pasaging (Iban.).

pasadsaran (Tagalog).—An ordinary inland water fish corral operated in Laguna de Bay for catching dalag migrating shoreward during high water (rainy season). It is made with two wings facing lakewards and converging into a heart-shaped enclosure which faces shoreward. Often, a canal is dug on shore to create a flow of lake water shoreward; hence the term "sadsad," which means to beach.

pasagad (Sebu Bisaya).—A deep-water fish corral in Bohol Province. The catch is brailed out with a sagad (scoop seine).

pasagka (Bikol).—A type of fish corral constructed across the outlets of Lake Buhi. It is provided with two wings but is devoid of a leader. One or more heart-shaped enclosures lead into the collecting crib where the catch is brailed out.

pasaging (Ibanag).—General term for fish corrals. *Synonyms:* Pasaking (Iban.); pasabing (Ilk.); baklad (Tag.).

pasalambang (Batangas Tagalog).—A drag or beach seine of cotton netting used in Bauan, Batangas Province.

pasalugki (Iloko).—A series of submerged V-shaped barricades for catching ipon (gobies). They are made of banana sheaths with a wall of cotton cloth stretched in front. The latter helps to clear the muddy water and thereby makes the ipon more active. Set against the current, this gear intercepts the fish which are finally caught in bubos at gates of the barricades. *Synonym:* Pasalugi (Ilk.).

pasalugi (Iloko).—A barricade for catching ipon (goby fry) in northern Luzon. *Synonyms:* Pasalugki or pasugki (Ilk.).

pasbang (Pangasinan).—Large river fish traps placed across the mouth of Dagupan River for catching fish migrating upstream with the rising tide. Each consists of two bamboo rafts built in V-shaped fashion, with an elevated platform and a sinamay bag for the collecting portion. *Synonym:* Pasagang (Ilk.).

pasbang-duble (Pangasinan-Spanish).—Two sets of the pasbang, using three bamboo rafts and two collecting bags in order to fish on both stages of the tide.

pasbang-sensilyo (Pangasinan-Spanish).—The simple style of operating the pasbang. Only one collecting bag is used, and it is fished during only one stage of the tide. *Synonyms:* Pasbang (Pang.); pasabang (Ilk.).

paserser (Iloko).—A triangular lift net operated in Vintar, Ilocos Norte Province, with the aid of a scareline.

pasgong (Sebu Bisaya).—A one-bamboo-joint crab trap for catching alikomo (land crab) in northern Mindanao. It is made with a spadelike bamboo strip trap door controlled by a bow-and-trigger arrangement. *Synonyms:* Patibong (Tag.; Ban. Bis.); sarading (Kuy.); lagpit (Il. Bis.); yagpit (Ak. Bis.).

pasikarod (Iloko).—A barricade for catching ipon with bubos (fish pots). The latter are anchored at the bottom by stone or rock weights and form the collecting device, as in pingi (Ilk.), a similar barricade for taking ipon.

pasol (Sebu Bisaya).—A handline or drop line used in deep water of the open sea for catching large fish, with or without the aid of light.

pasol-lambo (Sebu Bisaya).—A troll line. *Synonym:* Sibid-sibid (Tag.).

pasol-palangri (Sebu Bisaya).—A set longline in Negros Oriental Province.

pasol-pangutob (Sebu Bisaya).—A handline operated in Bohol Province for catching hasa-hasa (mackerel) with the aid of torchlight.

pasudsod (Iloko).—A longline in Solsona, Ilocos Norte Province. *Synonyms:* Pasursor (Ilk.); kitang (Tag.).

pasugki (Iloko).—A barricade for ipon (gobies) used in Aringay, La Union Province. *Synonyms:* Pasalugki or pasalugi (Ilk.).

pasurong (Iloko).—A barricade for ipon (goby fry) in Solsona, Ilocos Norte Province. It is constructed facing upstream to catch fish migrating downstream.

pasursor (Iloko).—A longline used in Solsona, Ilocos Norte Province. *Synonyms:* Pasudsod or basursor (Ilk.); kitang (Tag.).

patakiyob (Sebu Bisaya).—Rectangular drive-in-nets for taking mullet, siganids, whitings, and prawns. Made either of sinamay or cotton webbing, these nets are set either in a series or in a continuous line with barricades of twigs behind them. The fish are driven into the net by a number of fishermen. These actually are several sets of luob (Seb. Bis.), a trap net, operated together.

patalang (Bikol).—An encircling gill net much smaller than the bating (Tag.). Used for various kinds of fish, the meshes of the net and the thickness of the twine are adapted to the species sought. *Synonym:* Palubog (Bik.).

pataob (Tagalog).—A small, low, somewhat circularly set bamboo fish trap for taking dalag frequenting shallow, quiet coves near large bodies of inland waters. This gear is provided with a trap door. *Synonym:* Paluob (Tag.).

patapat (Pangasinan).—A fish shelter used particularly for shrimp. It consists of anchored piles of twigs and debris, and the catch is made by means of a push net. *Synonym:* Bumbon (Tag.).

pataw (Sebu Bisaya).—A type of line used in Calape, Bohol Province.

pataya (Iloko).—A barricade for catching ipon (goby fry) in rivers of northern Luzon. It consists of one main wall of cotton cloth supported by stakes. Behind this a series of leaders of banana sheaths is set perpendicularly to it, and bubos with mouths facing the current are placed between them. This term also refers to the sinamay hoop nets used as the collecting devices in the padait (Ilk.), another barricade for ipon.

pateng (Iloko).—A cylindrical fish pot for catching mullet during their downstream migration. It is tied to an anchor on the river bank and allowed to drift with the current, thus creating a suctionlike effect that draws the ludong (mullet) into its mouth. *Synonyms:* Pareng (Ilk. Iban.); gangen (Iban).

patibok (Tagalog).—A drive-in-net used in Navotas, Rizal Province. *Synonym:* Katigbi (Tag.).

patibog (Tagalog).—An encircling gill net for catching aligasin (mullet fingerlings). It is similar to, but smaller than the bating (Tag.). Once a school of these fish has been surrounded, the catch is made by driving and scaring them into the net with the aid of a wooden plunger.

patibong (Tagalog; Banton Bisaya).—A one-bamboo-joint crab trap provided at the open end with a spadelike one-bamboo-strip trap door controlled by a bow-and-trigger arrangement. It also has a small hole for admitting light at the closed end. The trap is inserted at the burrow opening to trap the animal, which has been attracted by the light. *Synonyms:* Sarading (Kuy.); lagpit (Il. Bis.); yagpit (Ak. Bis.).

patigbi (Ilongo Bisaya; Sambal).—A drive-in-net with scareline for catching small mullet, anchovies, and shrimp. The landing net, made like a shallow bag, is usually a light cotton netting of No. 20 sewing thread knitted by hand. Two men hold it in place, and two others drive the fish with the scareline. *Synonym:* Katigbi (Tag.).

patubog (Tagalog).—A fish trap in Lake Sampaloc, Laguna Province, for taking dalag. It consists of two parallel canals dug perpendicularly to the shoreline in order to simulate natural creeks. Entrances to these are filled with brush to attract the dalag. After closing the entrances with bamboo matting, the catch is made by hand or by dip net.

patukba (Tagalog).—A set pole and line for catching dalag. It is baited with a live frog and left unattended for some time. *Synonyms:* Lawin or lawing (Ilk.); palaway or paluay (Tag.).

patuktok (Iloko).—Pole and line fishing for dalag, using live frogs, earthworms, or fish for bait.

patudan (Pangasinan).—A pole and line.

patulid (Iloko).—A barricade for catching ipon. It is similar to the asar (Ilk.), except that split bamboo matting is used instead of mud and gravel. Also, instead of bubos (fish pots) forming the collecting device, an elevated bamboo platform, built to one side of the barricade, is used.

patulid-kileb (Iloko).—Barricades for catching ipon (goby fry) and other fish migrating downstream in Ilocos Sur Province. The collecting portion is made of two inclined bamboo platforms, with the one on the side set somewhat perpendicular to the river's course, and the other at the head of the trap set parallel to the current.

patuloy (Bisaya).—A set gill net operated with or without light from an anchored banca. The boat has two spreading bamboo booms projecting from both the bow and the stern. This gear is similar to the largarete (Tag.-Sp.) in Luzon.

patungkad (Samal; Taw Sug).—A handline or drop line in the Sulu Archipelago.

paturaw (Iloko; Pangasinan).—A set pole and line for catching dalag. Baited with a live frog, the gear is left for some time unattended.

paugmad (Bisaya).—A deep-water fish corral. Instead of collecting pounds it has two landing platforms placed on opposite sides of the semicircular enclosure. Here the catch is brailed out by a large scoop seine and dip nets. *Synonyms:* Habog (Sam. Bis.); bunsod-lapad (Seb. Bis.); tinagala (Bis.).

paugmad (Maranaw).—A fish corral set in from 8 to 10 fathoms of water in Lake Lanao. The catch is made with a scoop seine.

payakyak (Pangasinan).—A two-chambered fish corral constructed in from 3 to 5 fathoms of water in Lake Mangabul, Bayambang, Pangasinan Province. It consists of a series of fish weirs almost connected to each other by a winglike leader set across the entire width of a creek. This gear fishes during the receding water after the rainy season.

payaan (Aklan Bisaya).—Deep-water fish corrals of the inangkla (anchorlike) type in Panay Island, especially in the Aklan regions. *Synonym:* Palaan (Bis.).

payaw (Sebu Bisaya).—A fish shelter somewhat similar to the gango (Seb. Bis.). It is an anchored bamboo raft provided with coconut leaves and sometimes lighted on dark nights in order to attract the fish. The fish are caught from below this raft with a sigin (scoop seine). *Synonym:* Gulgo (Seb. Bis.).

penir (Pangasinan).—A fish corral constructed on a river bank. Two wings are set perpendicular to the single chamber so as to close completely that particular portion of the stream and catch fish with the receding water. This may also be classified as a barricade. *Synonym:* Populitin (Pang.).

pika (Iloko).—Handlines or drop lines fished from a banca or raft in Caoayan, Ilocos Sur Province.

pidpid (Bikol).—A filter net of sinamay for catching young shrimp during receding tide. *Synonym:* Saplad-para-alamang (Tag.).

pilangre (Dabawenyo).—A longline used in Davao for catching tuna and sharks. The gear has a distinctive Japanese influence, and its name is a corrupted Spanish term.

pinalusad (Sebu Bisaya).—A type of fish corral in Inabanga, Bohol Province.

piner (Samar; Pangasinan).—A river fish corral made with two wings and a collecting crib but no leader. The function of a leader is usually performed by one or both wings. *Synonym:* Bunuhan (Tag.).

pingi (Iloko).—A barricade for catching ipon (goby fry) in the Iloko Provinces. It consists of a staked sawali (webbed bamboo) fence with bubos (fish pots) planted at the base between the stakes to form the collecting portion. *Synonyms:* Better, etter, padait, or pamobuan (Ilk.).

pinid (Batangas Tagalog).—A set trap net about 100 fathoms long that is stretched across tidal reaches and fished during receding tide.

pinit (Tagalog).—A shallow-water fish corral in Macalelon, Quezon Province.

pipis (Tagalog).—A drive-in-net operated with a scareline in Pateros, Rizal Province. It is mounted on a triangular collapsible frame.

pisga (Iloko; Pangasinan).—A fish spear or harpoon fished from a raft.

plaan (Aklan Bisaya).—A type of fish corral in Pandan, Antique Province.

populitin (Pangasinan).—A one-chambered river fish corral or barricade set on one side of the stream with two wings constructed perpendicular to the enclosure, but parallel to the bank, so as to catch fish during ebb. This also may be merely staked bamboo mattings enclosing a definite portion of the stream along its bank in order to effect the capture of fish during receding water. *Synonym:* Penir (Pang.).

puket (Pangasinan; Iloko).—A set filter net for catching ipon (goby fry) along gradually shelving sandy shores near river mouths in the northern provinces. It is made either of sinamay or of coarse cotton cloth. *Synonym:* Tanggar (Ilk.).

pukot (Pilipino).—General term for various types of nets. Originally, this term referred to a beach or drag seine, usually made with a pocket, for taking sundry species of shore fish. It necessitated a large pulling crew on shore and often the whole population of a small barrio would participate in this operation. Recently, due to lack of basic knowledge of the differences among the many and varied kinds of nets, the term has been used as follows: An encircling gill net for sardines in the Negros Provinces and in Bantayan, Cebu; a scoop seine used for brailing out deep-water fish corrals of Zamboanga; a purse seine for taking tuna and bonito in Batangas Province; a bag net operated with the aid of light in many places in Mindanao. Also, in Jolo Island, this term has been applied to gear made of split bamboo matting, staked around the central portion and the wings operated like a beach seine.

pukot-alangan (Tagalog).—A drag seine, operated somewhat like a tuck seine, for taking kanduli (ariid catfish) and other species in water of about 2 fathoms depth in Laguna de Bay. It is similar to the pukot-laot (Tag.) in both its make and in its method of operation. It is much shorter and shallower however, measuring from 500 to 750 by 2 to 3 fathoms.

pukot-anod (Sebu Bisaya).—Drift nets operated in Ayungon, Negros Occidental Province.

pukot-asan (Kapampangan).—A cotton netting drag seine provided with a bag or pocket for catching asan (fish).

pukot-bangsi (Sebu Bisaya).—A purse seine used in the Visayas and northern Mindanao for catching bangsi (flying fish). Made of cotton netting, it varies in length from 115 to 150 fathoms, with a depth at the bunt of 8 fathoms or more. Purse rings are used at the latter region only. *Synonyms:* Pamarungoy, pukot-mangsi, and pukot-pamangsi (Seb. Bis.).

pukot-barimbaw (Tagalog).—A drag or tuck seine fished mainly for dalag in Laguna de Bay. It is made of cotton and measures 250 to 450 by 2 to 3 fathoms. It is similar to the pukot-laot and the pukot-alangan (Tag.) in its make and operation. Besides being shorter and shallower than these, however, it requires only one banca and a crew of from five to ten persons.

pukot-basnig (Sebu Bisaya).—A bag net operated from a sailing or rowed banca for catching schooling pelagic fish of moderate size. It is fished during the dark of the moon with the aid of lights.

pukot-binatoan (Sebu Bisaya).—A round haul seine in Bohol Province for catching tamban (sardines) and anduhaw (mackerel).

pukot-kanduli (Tagalog).—Term in Pililla, Laguna Province, for a drag seine used in Laguna de Bay for taking kanduli (ariid catfish) in deep waters. It has characteristics of a tuck seine, resembling the pukot-laot (Tag.). It is, however, longer and deeper than the pukot-alangan and the pukot-barimbaw (Tag.), and therefore necessitates use of more men and boats.

pukot-kasig (Samal; Taw Sug).—A gill net used with the aid of light for catching kasig (sardines). Measuring 30 by 6 fathoms, it is usually made of No. 30 sewing thread knitted with a mesh of 2 inches, stretched. It is equipped with wooden floats and stone sinkers.

pukot-kayagkag (Sebu Bisaya).—An encircling gill net fished mainly for sardines in Asturias, Cebu Province. The fish are scared by wooden plungers into entangling themselves.

pukot-dalag (Tagalog).—The smallest of the three types of drag seines used in Laguna de Bay mainly for taking dalag. Operated only in shallow water, just beyond the vegetation zone, it measures 100 to 250 by 1 to 2 fathoms. It has floats but no weights, and it has a bag or pocket. *Synonyms:* Pukot-gilid or barimbaw (Tag.).

pukot-gilid (Tagalog).—The same as a pukot-dalag. Its operation is somewhat like that of the tuck seine, and the catch is made by dip nets. *Synonyms:* Pukot-dalag or barimbaw (Tag.).

pukot-lamba (Sebu Bisaya).—A gill net operated in shallow waters for cavallas and groupers. The fish are scared into gilling by beating the water with bamboo sticks.

pukot-laot (Tagalog).—The largest of the three main types of drag seines fished in deeper waters of Laguna de Bay for kanduli (ariid catfish) and biya (gobies). From 1,000 to 1,500 fathoms long, it is hauled in the manner of a tuck seine. Five boats and from 30 to 50 men are required for its operation.

pukot-laot (Batangas Tagalog).—A tuck seine for catching tuna and other pelagic species in Batangas Province. Generally it is from 200 fo 250 by 10 to 15 fathoms and made of home-twisted cotton twine knitted with a mesh of 1 inch, stretched. It is operated by a crew of from 20 to 24 men in waters 35 to 50 fathoms deep. The closing or pursing of the bottom is effected either by dropping a weight or by divers hooking the ground lines together from each side.

pukot-libgaw (Sebu Bisaya).—A shore or drag seine in Cebu and Negros Oriental Provinces.

pukot-likom-likom (Sebu Bisaya).—A drive-in-net used with a scareline for taking reef species. *Synonym:* Bahan (Bis.).

pukot-likos (Sebu Bisaya).—An encircling gill net used in Ayungon, Negros Oriental Province.

pukot-likos-bato (Sebu Bisaya).—A reef drag seine used for catching rock fish in coral. This term is synonymous to ligkop (Sam. Bis.), a gear made of hand-knitted abaka twine. Operation includes the sinking of the cork line by three men aboard three bancas using bamboo poles. The ground line is watched constantly by divers who free the net from snags.

pukot-mamangsi (Sebu Bisaya).—A modified purse seine used in Medellin, Cebu Province, for catching flying fish. The purse rings are confined to the region of the bunt. *Synonyms:* Pukot-bangsi or pamarungoy (Seb. Bis.).

pukot-mamarungoy (Sebu Bisaya).—A stop seine used in Tuburan, Cebu Province, for catching barungoy (flying fish) with the aid of light and a sigin (scoop seine). The light is used for attracting the fish to a certain area where they can be surrounded and impounded by the pukot-mamarungoy and the sigin for brailing the catch out of the enclosure thus made.

pukot-mangsi (Sebu Bisaya).—A modified purse seine operated in Tabogon, Cebu Province, for catching bangsi (flying fish). The purse rings are confined to the region of the bunt. *Synonym:* Pukot-bangsi (Seb. Bis.).

pukot-mubgas (Sebu Bisaya).—An encircling gill net in Bohol Province for taking sardines. The fish, once encircled, are scared into gilling by using plungers or paddles. *Synonyms:* Salibot (Bis.); pukot (Seb. Bis.).

pukot-padlas (Sebu Bisaya).—A gill net used in Bohol Province which is similar to the padlas (Sam. Bis.). The net is first immersed in crushed shrimp so that the meshes become baited (smeared) with particles of shrimp meat.

pukot-padumog (Sebu Bisaya).—A gill net in Tuburan, Cebu Province. It is first immersed in crushed shrimp so that the meshes become baited (smeared) with shrimp meat. *Synonyms:* Padumog, pukot-padlas, or pamungbong (Seb. Bis.); padlas (Sam. Bis.).

pukot-pahubas (Sebu Bisaya).—A filter net made to fish during receding tide in Bohol, Agusan, Cebu, and Negros Oriental Provinces. *Synonym:* Budhi (Bis.).

pukot-pamalo (Sebu Bisaya).—A gill net for taking balo (garfish) in Konda, Cebu Province.

pukot-pamalubalo-kayagkag (Sebu Bisaya).—An encircling gill net used in Oslob, Cebu Province, for catching balo (garfish). A wooden plunger is employed to scare the fish into gilling.

pukot-pamangsi (Sebu Bisaya).—A modified purse seine for catching bangsi (flying fish) in Cawayan, Leyte Province. The purse rings are confined to the bunt or landing piece. *Synonym:* Pukot-bangsi (Seb. Bis.).

pukot-pamarungoy (Sebu Bisaya).—A purse seine for catching barungoy (flying fish) in Balamban, Cebu Province. *Synonym:* Pamarungoy (Seb. Bis.).

pukot-pamaubgas (Sebu Bisaya).—An encircling gill net operated in Cebu and Negros Occidental Provinces for taking mubgas (sardines).

pukot-pamubgas (Sebu Bisaya).—An encircling gill net used in Cawayan, Leyte Province, for catching mubgas (sardines). *Synonyms:* Pukot-mubgas or pukot-sa-mudgas (Seb. Bis.); salibot (Il. Bis.).

pukot-pamulinaw (Sebu Bisaya).—A drag seine operated in Balamban, Cebu Province, for taking bulinaw (anchovies).

pukot-pamuraw (Sebu Bisaya).—A round haul seine for catching buraw (short-bodied mackerel) in Cawayan, Leyte Province.

pukot-panalawasig (Sebu Bisaya).—A drag seine for catching salawasig (half-beak) in Oslob, Cebu Province.

pukot-panamban (Sebu Bisaya).—A round haul seine in Medellin, Cebu Province, for catching tamban (sardines). It is used both during the day and at night, preferably the latter, when it is operated with a light.

pukot-pang-araw (Batangas Tagalog).—A ring net operated only in the daytime in Batangas Province for taking tuna, bonito, and frigate mackerel. *Synonym:* Pukot-panulingan (Bat. Tag.).

pukot-pang-awa (Sebu Bisaya).—A gill net in Oslob, Cebu Province, for catching awa (spawning bangos).

pukot-pangdalag (Tagalog).—The smallest of the three main types of drag seines in Laguna de Bay used mostly for dalag. It is operated in the shallow waters a little beyond the vegetation zone. *Synonyms:* Pukot-dalag or pukot-gilid (Tag.).

pukot-panggab-i (Batangas Tagalog).—A purse seine used only at night for taking hasa-hasa (mackerel); galunggong (round scad); and miralya (slipmouth). It has a length equal to one-third of that of the pukot-pang-araw, is much deeper, and has much smaller meshes. *Synonym:* Pukot-pangmiralya (Bat. Tag.).

pukot-panggilid (Batangas Tagalog).—An ordinary beach seine for catching smaller species of fish such as anchovies, herrings, and sardines in Batangas Province. Made of sinamay or cotton netting, it is hauled toward the sloping smooth shores by a large crew.

pukot-panghagomaa (Sebu Bisaya).—A purse seine for catching hagumaa (mackerel) in Medellin, Cebu Province. *Synonyms:* Talakop or panghasa-hasa (Tag.); langbat (Sam. Bis.); lambat (Il. Bis.).

pukot-panghaol-haol (Sebu Bisaya).—An encircling gill net in Asturias, Cebu Province, for catching haol-haol (sardines). After the fish have been encircled, they are forced into gilling by wooden plungers or by beating the water with paddles. *Synonym:* Salibot (Bis.).

pukot-pangmiralya (Batangas Tagalog).—A purse seine used at night for taking miralya (slipmouth) in Batangas Province. *Synonym:* Pukot-panggabi-i (Bat. Tag.).

pukot-panlamba (Sebu Bisaya).—A beach or drag seine in Asturias, Cebu Province. *Synonym:* Panlamba (Seb. Bis.)

pukot-panulingan (Batangas Tagalog).—A ring net used during the daytime for catching large tuna, especially the tambakol (yellowfin). It has wider meshes than the pukot-panggabi-i or the pukot-pangmiralya (Bat. Tag.). *Synonyms:* Pukot-pang-araw or panambakol (Bat. Tag.).

pukot-panumbok (Sebu Bisaya).—An encircling gill net for catching sardines by encircling the school and forcing them to gill with the aid of panumbok (wooden plungers). *Synonym:* Pamaliling (Seb. Bis.).

pukot-paro (Kapampangan).—A filter net set at the gates of fishponds to catch paro (shrimp) when the water is being drained.

pukot-pataan (Sebu Bisaya).—A drive-in-net used in Bohol Province.

pukot-sa-mudgas (Sebu Bisaya).—An encircling gill net for catching mudgas (sardines). The fish, once encircled, are scared into gilling. *Synonym:* Salibot (Bis.).

pukot-taktak (Sebu Bisaya).—A drag or beach seine used in Sagod, Cebu Province. It is made of cotton netting and is operated on gradually shelving sandy or smooth shores. *Synonym:* Sinsoro (Pil.-Sp.).

pugad (Kapampangan).—A floating fish shelter about 3 feet in diameter for taking dalag. As the word implies, it is built in the form of a nest. It is made with a woven bamboo floor, walls of mud and grass, and a roof of thin straw. The nesting dalag enter through a small opening at the side. The fisherman, equipped with a panaklob or sukob (framed covering net) visits these nests periodically. Approaching the shelter cautiously, he covers it with the panaklob, while simultaneously placing one hand over the side opening to prevent the escape of the fish. The fish jump through the thin roof and land in the net. *Synonyms:* Bangkulong (Kap.); pugad-pugad (Tag.).

pugad-dalag (Tagalog).—A nestlike fish shelter for enticing dalag. The capture is made with a panaklob or sukob (framed covering net). *Synonyms:* Pugad or bangkulong (Kap.); pugad-pugad (Tag.).

pugad-pugad (Tagalog).—A nestlike fish shelter for luring dalag. The fish are hauled in with a panaklob or sukob (framed covering net). *Synonyms:* Pugad or bangkulong (Kap.); pugad-dalag (Tag.).

punor (Sambal).—A fish corral constructed across rivers in northern Zambales. It is provided with two wings flanking two antechambers, the latter opening into a tabagan (livebox) from which the catch is dipped out.

punot (Bisaya; Kuyonon).—General term for various types of fish corrals in the Visayas and Palawan. *Synonyms:* Baklad (Tag.); bungsod or bunsod (Seb. Bis.); bunuan (Sam. Bis.); sagkad (Bik.); pasabing (Ilk.).

punupon (Iloko).—A fish shelter of twigs and branches in Bantay, Ilocos Sur Province, for luring fish, especially shrimp. After the fish have been impounded by bamboo matting or netting, the debris is cleared and the fish brailed out. *Synonyms:* Rama (Ilk.); bumbon (Tag.).

puot (Iloko).—A barricade for catching ipon in Tagudin, Ilocos Sur Province.

puot (Samar Bisaya).—An encircling gill net for taking coral reef species.

pupok (Ibanag).—A fish shelter made of bunches of twigs for attracting fish and shrimp. Once impounded, the debris is cleared and the fish brailed out or picked up by hand. *Synonyms:* Bumbon (Tag.); rama (Ilk.).

pusil-pusil (Sebu Bisaya).—A bow-gun type of fish spear. Energy for releasing the long metal blade is furnished by a pair of stretched rubber bands operated trigger fashion. The gear is mounted on a gunlike wooden stock; hence, the term pusil-pusil, derived from "pusil" (gun; Bis.). *Synonym:* Pana (Tag.).

putos (Bikol; Bisaya).—A small drag seine made of sinamay, cotton netting, or banata (bamboo matting).

R

ragunot (Samar Bisaya).—A drive-in-net operated with a scareline.

rama (Iloko).—A fish shelter made of bunches of twigs and other debris for attracting fish. The catch is effected by various means after the fish have been impounded and the debris cleared. *Synonyms:* Arong (Sam. Bis.); konukon (Ilk.); bangkulong (Kap.); palamag or ramahe (Ilk.); bumbon (Tag.).

ramahe (Iloko).—A fish shelter made of twig bunches and other debris which is set or anchored in a convenient spot for attracting fish and shrimp. *Synonym:* Bumbon (Tag.); rama (Ilk.).

rama-tinarikan (Iloko).—A fish shelter made of twig bunches. Fish are impounded by a tarik, split bamboo matting (Ilk.).

rantaw (Maranaw).—A gill net for taking sardines, especially kasig. *Synonyms:* Lantaw, linge, or pukot-kasig (Sa.; T. Sug.).

raway (Maranaw).—A type of longline used in Lake Lanao.

raya (Samar Bisaya).—A cast net in Wright, Samar Province. *Synonyms:* Dala (Tag.); laya (Bis.).

rede (Tsabakano).—This term is the Spanish word for net and denotes either a cotton webbing drag seine or a sigin (scoop seine). The latter is a small net, fashioned like a purse seine, for brailing the catch from enclosures of deep-water corrals.

rineppet (Iloko).—A fish shelter made of twig bunches and debris tied together. After the debris has been cleared, the catch is collected by a skimming net. *Synonyms:* Bumbon (Tag.); rama (Ilk.).

rugmon (Banton Bisaya).—A fish shelter for luring fish which are captured by various means. *Synonyms:* Parugmon (Ban. Bis.); bumbon (Tag.).

S

sabay (Bikol).—A movable fish trap of bamboo matting constructed not far from shore. It consists of a pair of very long wings converging seaward into one or two collecting chambers, the last being the brailing place for the catch. This gear is set during rising tide and left until ebb when the fish, returning to deeper waters, are caught.

sabay (Sebu Bisaya).—A drag net or beach seine used in Balamban, Cebu Province. It is made with or without a pocket or bag.

sabukol (Pangasinan).—Cast nets used in Pangasinan Province. *Synonyms:* Dala (Tag.); laya (Bis.); tabukol (Ilk.); ataraya (Sa.-Sp.; T. Sug.-Sp.); lala (Samb.).

sabor (Sebu Bisaya).—A fish shelter in Cotabato Province for attracting fish and shrimp. It is composed of twig bunches and other debris set or anchored in convenient spots. *Synonym:* Bumbon (Tag.).

sakag (Tagalog).—A push net for taking shrimp and other shallow-water forms. It is made either of sinamay or cotton netting and is mounted on a collapsible, triangular frame. It is generally fished with or without the aid of light in wading depths. Recently, the operation of this gear has been extended to waters beyond wading depths, where it is fished from a banca or raft. Although when fished from a banca it is still called "sakag," the author has classified it under "skimming net," and has coined the Tagalog word "anod-sulong," due to this different mode of operation. In Lake Sampaloc, this gear has been modified further by mounting the framed net on a raft where a bamboo crosspiece acts as a fulcrum for lowering and hauling. *Synonyms:* Hudhod or sudsod (Bis.).

sakdit (Ivatan).—A triangularly framed push net operated in reverse fashion by pulling instead of pushing. The act is known as "mamaklid" or "mamaknid."

saklit (Tagalog; Kapampangan).—A push net fished with or without the aid of light for shrimp and other shore and bottom-dwelling fish. In some places in central Luzon, the term also designates a drag seine used in streams and fishponds for catching marketable bangos.

saklitan (Tagalog).—A fish corral constructed near river mouths for catching dalag. The catch is brailed out with a saklit (small drag seine).

saksakaw (Iloko).—A small drag net similar in design and construction to the kapot (push net; Ilk.). Instead of using a bamboo frame, women simply hold the saksakaw between their legs. *Synonym:* Saksaklang (Ilk.).

saksaklang (Iloko).—A small drag net held by women between their legs for catching small fish in the shallow streams of northern Luzon. *Synonym:* Saksakaw (Ilk.).

sakwal (Samar Bisaya).—A small tuck seine for catching anchovies and sardines. Made of sinamay and provided with a pocket, it is operated from two boats.

sakwat (Tagalog).—A push net fished for shrimp in Pililla, Rizal Province. *Synonym:* Sakag (Tag.).

sakyaw (Sambal; Iloko).—A drift net for catching siganids in Zambales Province and in northern Luzon.

sakyod (Tagalog).—A sinamay drag seine used in Rizal Province for catching shrimp. *Synonyms:* Sakyor or salap-hipon (Tag.).

sakyor (Tagalog).—A drag seine for taking shrimp in Paete, Laguna Province. *Synonyms:* Sakyod or salap-hipon (Tag.).

sada (Bikol).—A shallow-water fish corral that fishes with the receding tide in San Miguel Bay. It also is a term for a rock barricade built in reefs not far from shore for catching reef fish during ebbtide.

sadeng (Iloko; Sambal).—A set gill net operated in northern Luzon and Zambales Province for taking bilis (sardines) and purong (mullet). *Synonyms:* Pamilis or palned (Ilk.).

sadeng-pamaramban (Iloko).—A set gill net used in Ilocos Sur Province for catching tamban (sardines).

sadeng-pamilis (Iloko).—A set gill net in Ilocos Sur Province for catching bilis (sardines).

sagad (Iloko).—a type of fish rake used in the northern Luzon provinces.

sagad (Sebu Bisaya).—A scoop seine for hauling in the catch in deep-water fish corrals, direct from the semicircular enclosure. *Synonyms:* Sigin (Pil.); gayad (Tag.).

sagangat (Sebu Bisaya).—A three-pronged fish harpoon for catching sanga (devil ray). *Synonym:* Ese (Seb. Bis.).

sagap (Sambal).—A push net made either of sinamay or cotton netting. *Synonym:* Sakag (Tag.).

sagap (Iloko).—A small drag seine of either sinamay or fine-meshed cotton netting operated by two men. In some places in the Ilocos, it refers to a triangularly framed drive-in-net used with a scareline. If the former, it is synonymous to dundon (Ilk.), and if the latter, to parisris or parispis (Ilk.).

sagap (Batangas Tagalog; Bisaya).—A two-man drag seine for catching bangos fry. It is usually made of sinamay.

sagap-aramang (Iloko).—A small sinamay drag seine used in Santa Maria, Ilocos Sur Province, for catching aramang (shrimp fry). *Synonym:* Pamalaw (Bik.).

sagap-kon-pataray (Iloko).—A set drive-in-net used with a scareline in Narvacan, Ilocos Sur Province.

sagap-duron-duron (Iloko).—A push net operated in the rivers of Ilocos Norte Province.

sagap-dusdos (Iloko).—A sinamay push net used for taking ipon in Candon, Ilocos Sur Province. It is somewhat larger than the sayot (Ilk.).

sagkad (Bikol).—General term for fish corrals in the Bikol regions of southern Luzon, referring specifically to the shallow-water type (the original local style of fish weir). *Synonym:* Baklad (Tag.).

sagiwsiw (Bisaya).—A drive-in-net operated with a scareline.

sagop (Sebu Bisaya).—A barricade constructed as a complete enclosure in small rivers and creeks. The water is first bailed or drained out, and the fish are then picked up by hand or caught with cover pots.

sagudsod (Kapampangan).—A modified half-cone-shaped fish scoop for catching gobies, shrimp, and dalag. Measuring about 30 feet long from the mouth to the tip of the bag, it is made of webbed bamboo splints with a rigid opening and is provided with a handle. In operation it is pushed, and a scareline is used.

saguysoy (Sebu Bisaya).—A collapsible and triangularly framed drive-in-net operated with a scareline. *Synonyms:* Konay or solambaw (Sam. Bis.).

sahakeb (Ivatan).—Dip nets of fine mesh for catching eels and shrimp.

sahapang (Samal; Taw Sug).—A three-pronged fish spear having a wooden or bamboo handle or shaft.

sahid (Bisaya; Bikol)—A cotton-netting drag seine made like a bag. Measuring 3 fathoms long by 4 feet at the mouth, it has wooden struts or spreaders crossing the net vertically near the mouth. These keep the mouth distended while the gear is dragged in the manner of an ordinary beach seine.

sahid-sahid (Sebu Bisaya).—A skimming net for catching small and young shrimp in northern Mindanao. It is mounted on a triangular or oval bamboo frame and operated from a banca or a platform set along the river bank. *Synonym:* Sarap (Seb. Bis.).

sahid-salibut (Sebu Bisaya).—A drift net found in Bohol Province.

sahid-sinurambaw (Sebu Bisaya).—A set drive-in-net operated with a scareline in Loon, Bohol Province. Made of sinamay, it measures 15 by 9 feet. Three sides are mounted on three bamboo poles, forming a rectangle, with one side free.

sahuran (Aklan Bisaya).—A fish corral consisting of a central collecting pound flanked by two long wings. It is set in rivers or along the shore and fishes during receding tide.

sain-sain (Sebu Bisaya).—A round haul seine for catching schools of anchovies, sardines, and mackerel. It is operated from two boats during the dark of the moon with the aid of powerful petroleum lamps. *Synonym:* Sapyaw (Pil.).

sala (Tagalog).—A filter net for catching shrimp. *Synonyms:* Diyakus or dayakus (Tag.).

salakab (Tagalog; Bisaya).—A conical or sub-cylindrical cover pot about 3 feet high. It is made of split bamboos, tied in parallel series to loops or circular frames. It has a wide lower opening, about 2 feet in diameter, but only a small hole at the top. The latter is just large enough to permit inserting one hand for the recovery of the catch, after the gear has been stuck in the mud by the other hand. *Synonyms:* Tallakeb or asad (Ilk.); taklob (Il. Bis.); talakeb (Pang.).

salambaw (Tagalog).—A huge lift net operated mainly for mullet. It is mounted and fished like a lever net from a large bamboo raft in rivers and near river mouths.

salambaw (Pangasinan).—A rectangular lift net used in rivers. One side is supported by poles with a block-and-tackle arrangement, and the opposite side is held by two men from a platform built along one side of the river. It is fished like a blanket net. *Synonym:* Salambaw-parigdig (Pang.).

salambaw (Sambal; Bikol-Tagalog; Bisaya).—A square lift net for catching mullet in rivers. It is operated by four men from four bamboo tripods, one to each corner. *Synonyms:* Kabyaw-ha-salog or konay (Sam. Bis.).

salambaw-basnig (Bikol).—A bag net for taking anchovies, sardines, mackerel, and round scad. Made of fine-meshed cotton twine, it is operated from a banca which is generally outriggered. This net is fished during the dark of the moon with the aid of a powerful lamp. *Synonym:* Basnig (Pil.).

salambaw-bugton (Pangasinan).—A triangularly framed lift net operated by only one man.

salambaw-inalong (Pangasinan).—A stationary lift net. Rectangular in form, it is set near the bank with the anchored side attached to two poles toward midstream. The opposite hauling side is manipulated by two retrieving lines from a sheltered bamboo platform toward the river bank. "Alalong" means watch tower.

salambaw-parigdig (Pangasinan).—A rectangular lift net weighted at each corner. In operation, one side is tied to two poles with a block-and-tackle arrangement, while the opposite side is held by two men from a bamboo platform on the river bank. Fishing this gear resembles the blanket net operation. *Synonym:* Salambaw (Pang.).

salanguwang (Iloko).—A bamboo fish pot used in Ilocos Sur Province.

salap (Batangas Tagalog).—A sinamay push net. *Synonyms:* Hodhud (Il. Bis.); sakag (Tag.).

salap (Sambal).—A rectangular lift net mounted on two bamboo crosspieces and operated by one man with the aid of an inverted T-like plunger. *Synonyms:* Kasag (Tag.); kasad (Ilk.).

salap (Tagalog).—Two distinct types of fishing gear for catching shrimp in the thickly weeded sections of Laguna de Bay. One type is a dip net, measuring slightly more than 3 by 3 feet, that is used for dipping or scooping shrimp from a banca. The other net is used like a skimming net, with or without the aid of light. It is mounted either on a triangular frame or simply attached to two bamboo poles crossed at one end. In Batangas, the term refers to either a sinamay drag net for taking bangos fry, or to a sinamay push net for catching shrimp. In the former case the term is synonymous to the sagap, drag seine (Bat. Tag.).

salapang (Tagalog; Bisaya).—An ordinary fish spear with a wooden or bamboo shaft and one or more barbed metal blades. It is generally used with the aid of light.

salap-balaw (Bikol).—A small, two-man drag seine of sinamay made with a pocket for catching balaw (small shrimp). *Synonyms:* Pamalaw or sarap-sa-balaw (Bik.); salap-hipon (Tag.).

salap-hipon (Tagalog).—A drag seine operated in Laguna de Bay for taking shrimp. It is made either of sinamay or of santi (China grass) netting. *Synonyms:* Sarap-sa-balaw or pamalaw (Bik.).

salibot (Bisaya).—A cotton encircling gill net for catching sardines. It is much smaller than the bating or halang (Tag.), but like the latter gear, fish are forced into gilling by beating the water with paddles and poles. *Synonym:* Pukot-sa-mudgas (Bis.).

salibot (Sebu Bisaya).—A drag seine of fine cotton netting employed in Lake Maimit for catching dalag and clariid catfish.

salilo (Aklan Bisaya).—A deep-water fish corral in Iloilo and Capiz Provinces. It consists of a leader, a large semicircular enclosure, two somewhat triangular chambers, and a circular collecting crib.

salimpukot (Sebu Bisaya).—A small cotton drag seine operated by four men. *Synonym:* Salibot (Seb. Bis.).

saliwsiw (Bikol).—A rake used in southeastern Luzon.

saliwsiw (Banton Bisaya; Aklan Bisaya).—A drive-in-net which consists of a triangularly framed lift net and is operated with a scareline. *Synonyms:* Hanig (Bis.); kulokutok (Tag.).

salok (Tagalog).—A dip net used in Laguna de Bay for brailing out the catch from fish corrals or from the bag or bunt of seines.

salubang (Kuyonon; Aklan Bisaya).—A multi-bladed fish spear with a wooden or bamboo shaft. It is usually operated with the aid of a torch or lamp. One type used in Antique Province for spearing fish and turtles has barbless blades, including a much stronger and longer barbless metal blade in the center. *Synonyms:* Salapang or tiksal (Tag.).

salungat (Subanon).—A fish corral found in Dapitan, Zamboanga Province. *Synonym:* Sinudlay (Sub.).

saluran (Bisaya).—A shallow-water fish corral built on coral reefs or along the shore for fishing during receding tide. *Synonyms:* Pahubas (Bis.); sahuran (Ak. Bis.).

salwag (Igorot).—A cast net used in Mountain Province.

salyang (Pangasinan).—A lift net for catching crabs. It is small, square, coarse-meshed, and mounted on split bamboo crosspieces. It is baited before being fished. *Synonyms:* Bintol (Pil.); bentoy (Ban. Bis.); sellem (Ilk.; Iban.).

salyang (Iloko).—A small, somewhat funnel-shaped bamboo fish pot which is set at openings of paddy field dikes for catching fish while the water is being drained.

sampay (Maranaw).—A tuck seine used for catching young sardines. This seine is operated in conjunction with gill nets which are used to drive the sardines into the seine. Incidental to this operation, flying fish are caught in the gill nets.

sankal (Bikol).—A push net. Made either of cotton or sinamay, it is triangularly framed, collapsible, and is provided with runners. *Synonym:* Sakag (Tag.).

saneb (Iloko).—A river barricade for catching mullet and theraponids. It is set so that the fish will be concentrated near the bank where a part of the barricade forms a pasturelike enclosure. The catch is made by cast nets thrown from the bank.

sangab (Sebu Bisaya.)—A small, round haul seine in Mindanao for taking live bait used in jack-pole fishing for tuna. *Synonym:* Kubkobilyo (Sam.; Bis.-Sp.).

sangat (Sebu Bisaya).—A fish corral found in Jetafe, Bohol Province.

sapang (Samal; Taw Sug; Sebu Bisaya).—A fish spear.

sapang-kong-antipara (Sebu; Bisaya-Spanish).—A fish spear used by a diver fisherman wearing goggles.

saplad (Pilipino).—A staked filter net for catching bangos fry. It is made of sinamay with wings of split bamboo matting. *Synonym:* Saplar (Ilk.).

saplad (Tagalog).—A barricade used in Kainta, Rizal Province.

saplad-para-alamang (Tagalog).—A set filter net for taking alamang (small shrimp) during ebbtide. Made with a bag and wings of sinamay, it is employed along shallow, gradually sloping, sandy beaches with the aid of long dikes of sand and mud. *Synonyms:* Pidpid (Bik.); dayakus or diyakus (Tag.); ampis (Bis.).

saplar (Iloko; Ibanag; Pangasinan).—A staked filter net for taking shrimp. *Synonym:* Saplad (Pil.).

sapyar (Ibanag).—A staked filter net for taking shrimp. *Synonym:* Saplad (Pil.).

sapyaw (Pilipino).—A round haul seine used during the dark of the moon for catching pelagic species that run in schools, such as anchovies, sardines, and mackerel. Made of cotton netting, it is operated from two boats with the aid of lights. *Synonyms:* Iwag (Il. Bis.); sapyaw-kon-luses (Sam. Bis.); kabyaw (Bik.); lawag (Sam. Bis.).

sapyaw (Batangas Tagalog).—A gill net for catching anchovies and young sardines with the aid of light.

sapyaw (Bikol).—A lift net used in San Miguel Bay and Masbate Province chiefly for mullet. Triangular in shape, it is built on two bamboo crosspieces which are mounted on one side of a banca. Operated as a drive-in-net from the tilted banca, it takes fish driven by two men with a long scareline.

sapyaw (Bikol; Bikol-Tagalog).—A skimming net used for catching sibubog or galunggong (round scad) along the east coast of southern Luzon, including Quezon Province. Fished during the daytime, it is operated underneath fish shelters made of bamboo rafts and coconut leaves.

sapyaw-kon-luses (Bisaya-Spanish).—A round haul seine fished during the dark of the moon for pelagic species such as anchovies, sardines, and mackerel. Made of cotton netting, it is operated with a pair of big bancas and several smaller lighted boats. *Synonyms:* Sapyaw (Pil.); iwag (Il.-Bis.); lawag (Sam. Bis.).

sapyaw-de-kuwerdas (Samar Bisaya-Spanish).—This is a term for an old version of the current sapyaw (Pil.). It was originally operated in daytime only. *Synonyms:* Sapyaw-ordinaryo (Sam.; Bis.-Sp.); kabyaw-ordinaryo (Bik.-Sp.).

sapyaw-lawag (Samar Bisaya).—A round haul seine used with a light during the dark phases of the moon. *Synonyms:* Lawag (Sam. Bis.); iwag (Il. Bis.); sapyaw-kon-luses (Bis.-Sp.).

sapyaw-lawagan (Samar Bisaya).—A round haul seine used with a light during the dark phases of the moon. *Synonym:* Sapyaw-lawag (Sam. Bis.).

sapyaw-ordinaryo (Samar Bisaya).—A round haul seine used in daytime only. *Synonym:* Sapyaw-de-kuwerdas (Sam. Bis.-Sp.).

sapyaw-sa-boya (Bikol-Spanish).—A skimming net used chiefly for round scads. It is fished underneath fish shelters consisting of anchored rafts of bamboo and coconut leaves. "Boya" refers to the fish shelter. *Synonyms:* Sapyaw (Bik.; Bik.-Tag.).

sapyaw-sa-gilid (Bikol).—A dip net found in Albay Province.

sapyaw-sa-hapon (Sebu Bisaya).—A type of Japanese round haul seine (shibari-ami) employed before World War II in Imuran Bay, Palawan, for taking hasa-hasa (mackerel). It was fished by the Japanese in daytime only.

sara (Bikol-Spanish).—A barricade found in Tayabas and Camarines Sur Provinces.

sarabay (Kuyonon).—A push net used in Palawan Province.

sarading (Kuyonon).—A one-bamboo-joint crab trap. A trap door at the open, nodeless end is controlled by a bow-and-trigger arrangement. The gear is set at the opening of a crab burrow so that the animal itself releases and closes the trap door. *Synonyms:* Patibong (Tag.); lagpit (Il. Bis.); yagpit (Ak. Bis.).

sarap (Bisaya; Kuyonon; Bikol).—A sinamay drag or beach seine ordinarily provided with a pocket or bag. In Samar Province, it measures 75 by 20 feet and is fished for shrimp. In Masbate Province, the term refers to a sinamay tuck seine used for pelagic species such as tuna and sardines. *Synonym:* Gulgol (Sam. Bis.).

sarap (Iloko).—A barricade for catching ipon (goby fry) in which fish pots (bubos) form the collecting devices.

sarap (Sebu Bisaya).—In northern Mindanao, this term refers to a shallow-water trap net set in rivers by short stakes. It consists of two wings and a bag. Set facing downstream, it catches gobies during their upstream migration. In this case, the bag is tied to a pole in order to keep the mouth open.

sarap-banata (Bisaya).—A small drag seine of sinamay for catching shrimp and bangos fry.

sarap-para-balat (Samar Bisaya).—A small drag seine of sinamay for gathering balat (sea cucumber).

sarap-para-hipon (Samar Bisaya).—A small drag seine for taking shrimp (hipon). *Synonym:* Sarap (Bis.).

sarap-sa-balanak (Bikol).—A sinamay drag seine used in San Miguel Bay for catching balanak (mullet).

sarap-sa-balaw (Bikol).—A two-man drag seine operated in San Miguel Bay for catching balaw (small shrimp). Made of sinamay, it is provided with a pocket. *Synonym:* Pamalaw (Bik.).

sarapang (Bikol).—A fish spear used in the Bikol regions.

sarawsaw (Ilongo Bisaya).—A somewhat cubical bag net operated in rivers for catching gobies and dalag. It is fished by four persons, one to each corner, who disturb the surface water and intermittently lift the net to capture the scared fish.

sarep (Iloko).—A shallow-water barricade for catching ipon (goby fry). It is set in water about 5 feet deep, and rows of bubos (fish pots) form the collecting portion.

sariwsiw (Pangasinan).—A set lift net of triangular shape mounted on two collapsible bamboo crosspieces. It is operated like a drive-in-net with a scareline. *Synonyms:* Konay or solambaw (Sam. Bis.).

sasad (Iloko).—A drive-in-net in Ilocos Sur Province which is operated with poles for beating the water instead of the conventional scareline.

sawayagan (Ilongo Bisaya).—A sinamay drag seine, measuring 10 by 1 fathom, which has no pocket or bag.

sawsaw (Samal; Taw Sug).—A dip net.

sayanggong (Iloko; Ibanag).—A round haul seine made of sinamay and operated with the aid of lights. *Synonym:* Sapyaw (Pil.).

sayanggong-sapyaw (Iloko).—A round haul seine of sinamay. *Synonyms:* Sapyaw (Pil.); sayanggong (Ilk.; Iban.); kurokod-partigo (Ilk.).

sayap (Banton Bisaya; Aklan Bisaya).—A beach or drag seine of sinamay or cotton usually provided with a bag or pocket. *Synonym:* Pukot (Pil.).

saykit (Tagalog).—A two-man drag seine for catching shrimp. Made of sinamay, it has two short wings and a long bag. *Synonym:* Pamalaw (Bik.).

sayding (Iloko).—An octopus jig similar to the squid jig. Baited with crab, it consists of a leaded jig bearing a circle of barbless hooks toward the free end.

sayok (Ibanag).—A triangular lift net with a pocket for catching bangos fry. It is much larger than the kapot (Ilk.). *Synonym:* Sayot (Ilk.).

sayod (Aklan Bisaya).—A drag net for taking bangos fry. It is made of sinamay and has no pocket. *Synonym:* Sagap (Bat. Tag.; Bis.).

sayod (Iloko).—A filter net of sinamay for catching shrimp, gobies, and bangos fry. *Synonym:* Diyakus (Tag.).

sayot (Iloko).—A triangularly mounted lift net provided with a pocket for taking ipon (goby fry). This gear is larger than the kapot (Ilk.). *Synonym:* Sayok (Iban.).

sayring (Pangasinan).—A small trawl net operated from two anchored boats. The net is dragged in grounds where fish shelters have been placed a few days beforehand. The debris composing the shelters is cleared before the net is used.

sayudsod (Iloko).—A push net. *Synonym:* Sakag (Tag.).

sayursor (Sambal).—A push net. *Synonym:* Sayudsod (Ilk.).

seket (Tagalog).—A triangular drive-in-net operated in Laguna de Bay for catching kanduli (ariid catfish). It is fished with a scareline made to drag along the bottom. *Synonym:* Udaod (Tag.).

sellem (Iloko; Ibanag).—A small, square, baited lift net for catching crabs. *Synonym:* Bintol (Pil.); bentoy (Ban. Bis.); salyang (Pang.).

serada (Bisaya-Spanish).—An estero barricade of stones and rocks for trapping fish during low tide.

sera-sera (Ilongo Bisaya-Spanish).—A fish corral found in Iloilo and Capiz Provinces similar to the pahubas (Bis.). It is fashioned with a collecting pound and fishes during receding tide.

sibat (Tagalog; Bisaya).—A fish spear with a wooden or bamboo shaft, to one end of which is attached one or more blades.

sibbing (Iloko).—A simple one-chambered river barricade for catching shrimp and small fish. It consists of a dam which guides fish into the gate where a pot forms the collecting device. It is generally fished at night with light.

sibid-sibid (Tagalog; Bisaya; Bikol).—A general term for troll lines. *Synonyms:* Pahila (Tag.); paguyod (Bis.); subid-subid or pasol-lambo (Seb. Bis.).

sibot (Tagalog; Aklan Bisaya; Bisaya).—A dip net of various types used to brail out catch in corrals and nets. It is also a gear used in fishing from a boat with aid of lights.

siklong (Pangasinan).—A one-bamboo-joint crab trap operated with a bow-and-trigger controlled trap door for catching land crabs as they crawl from their burrows. *Synonyms:* Patibong (Tag.; Ban. Bis.); sarading (Kuy.); lagpit (Il. Bis.).

sikpaw (Pilipino).—A dip net, similar to the tikpaw (Bis.), which is usually operated from a banca with the aid of light.

sikpaw-pamangsi (Sebu Bisaya).—A dip net used in Bohol Province for catching mangsi (flying fish) with the aid of light.

sigay (Iloko).—General term for gill nets in northern Luzon. When used in rivers, it is a drift net. When employed in sea fishing it is an encircling gill net.

sigay (Sambal).—A cotton gill net for catching various species such as mullet and sardines. The mesh size is adapted to the kind of fish sought.

sigay-palayupoy (Iloko).—A drift net used in Ilocos Norte Province. It is made of very light twine, usually of Nos. 70 or 80 cotton sewing thread.

sigay-sa-awa (Iloko).—A drift net for taking awa (spawning bangos) in La Union Province.

sigin (Pilipino).—A scoop seine with purse rings which is used for brailing out the catch direct from semicircular enclosures of deep-water fish corrals. *Synonyms:* Gayad (Tag.); sagad (Seb. Bis.).

sigpaw (Bisaya; Bikol-Tagalog).—A dip net used especially for fishing from a boat with a light. *Synonyms:* Tigpaw or sikpaw (Pil.).

sihod (Sebu Bisaya).—This term refers to either of two distinct classes of gear, both used for brailing out the catch from fish corrals in southern Mindanao. If made of non-textile material, it is a fish scoop; if made of textile material, it is a dip net.

siid (Tagalog; Pangasinan).—A small, low, heart-shaped potlike trap used chiefly for catching clariid catfish (hito). Made of bamboo matting and baited, it is designed with a nonreturn device. *Synonyms:* Umang, dakikong, bakikong (Tag.).

siir (Pangasinan).—A set pole and line in which the short pole is stuck in the ground. It does not require constant attention.

siir (Sambal).—A small, potlike trap for catching hito (clariid catfish). *Synonyms:* Siid (Tag.; Pang.); hiir (Samb.).

siir-na-alalo (Pangasinan).—A set pole and line for catching alalo (climbing perch) in the Mangabul fisheries, Bayambang, Pangasinan Province.

siir-na-paltat (Pangasinan).—A set pole and line for catching paltat (clariid catfish) in the Mangabul fisheries, Bayambang, Pangasinan Province.

silew (Pangasinan).—A set pole and line for catching paltat (clariid catfish) in the Mangabul fisheries, Pangasinan Province. *Synonym:* Siir-na-paltat (Pang.).

silhig (Banton Bisaya).—A fish trap of split bamboo matting operated with the aid of a scareline.

silo (Tagalog).—A snare used in Navotas, Rizal Province, for catching alimasag, a swimming crab. It consists of a noose of fine split rattan tied to the tip of a short bamboo pole.

silo (Bikol).—Dip nets used in Camarines Norte Province.

silot (Pangasinan).—A deep-water tuck seine operated from a boat. Its meshes are wider than those of the karukod or daklis (Ilk.; Pang.).

silot (Iloko).—A set gill net operated in northern Luzon for taking kabasi (gizzard shad). It measures 200 by 2 fathoms and has a mesh of 2½ inches, stretched.

sima (Tagalog).—A cover pot used in Morong, Rizal Province. *Synonym:* Salakab (Tag.).

sima (Batangas Tagalog).—A small, triangularly framed dip net for taking shrimp and fish from a fish shelter.

sinapyaw (Ilongo Bisaya).—A small beach seine, designed like a round haul seine, that is operated near the coast in Estancia, Iloilo Province.

sindok (Samar Bisaya).—A collapsible, triangularly framed skimming net. Actually, it is a push net without runners.

sinipete (Tagalog-Spanish).—A shallow-water fish corral designed with a leader, two wings, and two or three graduated connecting chambers. The smallest terminal compartment serves as the collecting pound. *Synonym:* Bunuan-ordinaryo (Sam. Bis.).

sinog-an (Sebu Bisaya).—A type of fish corral in Jetafe, Bohol Province.

sinsoro (Pilipino-Spanish).—A general term for a cotton netting drag or beach seine, with or without a bag. It is derived from the Spanish word "chinchorro," meaning beach seine. *Synonyms:* Bolitse (Bik.); pukot-taktak (Seb. Bis.); tsintsoro (Pil.-Sp.); pukot (Pil.).

sinsoro-hapones (Pilipino-Spanish).—A cotton webbing drive-in-net for catching dalagang bukid (caesios) and labahita (surgeon fish). Made with two wings and a bag, it is set among reefs in water from 3 to 10 fathoms where a concentration of the fish has been spotted. The fish are driven into the bag by a cordon of fishermen, each carrying a pendant or a short, vertical scareline. The catch is then brailed out into bancas and thence to the hold of a mother boat. The term refers to the "muro-ami," a Japanese drive-in-net introduced to the Islands by Okinawa fishermen before World War II.

sinsoro-panalikop (Batangas Tagalog).—A purse seine for catching tuna. It measures 150 by 3 fathoms. *Synonyms:* Panalikop or panuligan (Bat. Tag.).

sinsoro-pangdayo (Batangas Tagalog).—A purse seine used in Bauan, Batangas Province, for catching tuna offshore. It may be as long as 250 fathoms.

sinsoro-panggilid (Batangas Tagalog).—A shore or beach seine used in Lobo, Batangas Province.

sintak (Sebu Bisaya).—A pole and line operated by one fisherman from a dugout. Both pole and line are 15 feet long and are fished with a fish-shaped bone lure with a barbless hook. It is similar to jack-pole fishing for skipjack, used by Japanese in the Philippines, except that no live bait is used.

sintsoro (Sebu Bisaya-Spanish).—A cotton netting beach or drag seine, usually made with a bag or pocket, that is operated along smooth, gradually shelving sandy shores. It is derived from the Spanish word "chinchorro," meaning beach seine. *Synonyms:* Pukot (Tag.); sinsoro or tsintsoro (Pil-Sp.).

sinudlay (Subanon).—A type of fish corral found in Dapitan, Zamboanga Province. *Synonym:* Salungat (Sub.).

sipayot (Iloko).—Dip nets used in La Union Province.

sira (Ilongo Bisaya-Spanish; Aklan Bisaya-Spanish).—A movable, shallow-water fish corral built during lowest tide along mudflats in the intertidal zone. It has a large number of collecting pounds but no leaders, and it fishes during receding tide. *Synonym:* Pahubas (Bis.).

sisilo (Ivatan).—A long-handled dip net operated with the aid of a light from the bow of a banca. *Synonyms:* Tikpaw (Bis.); tigpaw (Tag.).

siwasiw (Pangasinan).—A pole and line for catching dalag. Live frog bait is used, and the gear is swung continuously back and forth.

sodsod (Bisaya).—A push net, usually made of sinamay, that is mounted on two collapsible bamboo poles with wooden runners. *Synonym:* Sakag (Tag.).

solambaw (Samar Bisaya).—A triangularly framed drive-in-net set within wading depths and fished with a scareline. *Synonyms:* Konay or sulambaw (Sam. Bis.).

solero (Ilongo Bisaya).—A type of fish corral used in Ayuy, Iloilo Province.

songkit (Sebu Bisaya).—A fish spear found in Bantayan, Cebu Province.

sowal (Samar Bisaya).—A sinamay tuck seine for taking young sardines and mackerel in Samar and Leyte Provinces. *Synonym:* Sakwal (Sam. Bis.).

subid-subid (Sebu Bisaya).—Troll lines. *Synonym:* Sibid-sibid (Tag. Bis.; Bik.).

sukob (Tagalog).—A cover net used to cover the nestlike fish shelters (pugad-pugad) for taking dalag. It is made with a rigid circular frame at the mouth. *Synonym:* Panaklob (Tag.).

sukob-ayungin (Tagalog).—A cover net for catching ayungin (silver grunt). It is a similar to the panaklob or sukob (Tag.), but it is a lighter gear and is provided with a handle.

sukob-kanduli (Tagalog).—A cover net, also similar to the panaklob or sukob (Tag.), which is used for catching kanduli (ariid catfish).

sukob-dalag (Tagalog).—A cover net for taking dalag (murrel) that is similar to the panaklob or sukob (Tag.).

sukod (Kapampangan).—A cover net used in Pampanga. *Synonym:* Sukob (Tag.).

sudsod (Bisaya).—A push net, usually made of sinamay, that is mounted on a collapsible, triangular frame.

sugabaw (Ilongo Bisaya).—A shallow-water fish corral found in Escalante, Negros Occidental Province. *Synonym:* Taba (Bis.).

sulambaw (Samar Bisaya).—A triangularly framed set drive-in-net that is operated with a scareline. *Synonyms:* Konay or solambaw (Sam. Bis.).

sulambaw-sin-asta (Samar Bisaya).—A push net used in Wright, Samar Province. Literally, it means a lift net without asta (scareline). *Synonym:* Sakag (Tag.).

sulong (Batangas Tagalog).—A push net in Batangas Province. *Synonym:* Sakag (Tag.)

sulyang (Tagalog).—A large, cylindrical bamboo fish pot placed in the collecting pounds or cribs of deep-water fish corrals. It is set with the wider opening of the funnel or non-return valve uppermost, so as to catch fish diving from surface to bottom.

sunggapong (Iloko).—A long-handled dip net with an oval mouth fished with a light from the prow of a boat. *Synonym:* Tigpaw (Tag.).

sungya (Bisaya).—A hand scoop, with handle, for taking shrimp and crabs. It is about 2 by 3 feet. Dragged and pushed in all directions, it may be operated with a scaring device or merely with the foot of the fisherman serving that purpose.

surambaw (Bikol; Bisaya).—A rectangular, triangular, or cubical lift net of sinamay operated with a scareline.

surambaw-hapones (Bisaya-Spanish).—The term used in Ayungon, Negros Occidental Province, for the "muro-ami" (Japanese drive-in-net) which is fished in coral reefs for caesios (dalagang bukid) and surgeon fish (labahita).

surambaw-paligid (Ilongo Bisaya).—A drive-in-net used with a scareline.

T

taan (Bikol; Bisaya).—A barricade of stones and split bamboo matting used in Siruma, Camarines Sur Province, for catching coral reef species. In the Visayas, this is made entirely of stones.

taan (Sebu Bisaya).—Longlines used in northern Mindanao for inland-water fishing. *Synonym:* Kitang (Tag.).

taba (Bisaya).—Shallow-water fish corrals found in Romblon Province and Panay Island. *Synonym:* Baklad (Tag.).

tabak (Iloko).—A small drag seine for river fishing. It is made of cotton netting and is designed with a pocket or bag.

tabag (Ibanag).—A small drag seine used in Cagayan Province for river fishing. Made of cotton netting, this seine has no pocket.

tabal (Pangasinan).—In the inland fisheries of Mangabul, this refers to a gill net with or without sinkers. In the sea fisheries of Pangasinan Province, the term refers to a small-meshed drag seine operated in waters 1 fathom or less in depth.

tabal-kon-bato (Pangasinan).—A submerged set gill net with a weighted groundline and a floatline of saluyot strings.

tabal-kon-paltaw (Pangasinan).—A floating set gill net, with floats on the corkline, which is used in pelagic fishing.

tabal-grande (Pangasinan-Spanish).—A small-meshed drag seine used in waters 15 fathoms or more in depth.

tabal-pikinyo (Pangasinan-Spanish).—A small drag seine fished in waters less than 1½ fathoms deep.

tabar (Pangasinan).—A drift net operated in the inland-water fisheries of Bayambang, Pangasinan Province.

taba-taba (Aklan Bisaya).—A simple type of shallow-water fish corral used in Panay, Capiz Province. Made without long wings, it is flanked by a central collecting pound. It is set along mud flats and fishes during ebbtide. *Synonym:* Saluran (Ak. Bis.).

tabon (Bisaya).—A fish pot. *Synonym:* Bubo (Tag.).

tabukol (Iloko).—Cast nets. *Synonym:* Dala (Tag.).

tabukol-areb (Iloko).—A cast net used in Solsona, Ilocos Norte Province.

tabukol-baybay (Iloko).—A cast net fished in marine waters in Ilocos Sur Province. *Synonym:* Tabukol-panaaw (Ilk.).

tabukol-karayan (Iloko).—A cast net used in rivers and inland waters in Ilocos Sur Province. *Synonym:* Tabukol-panarayan (Ilk.).

tabukol-pamaltat (Iloko).—A cast net for taking paltat (clariid catfish).

tabukol-panaaw (Iloko).—A cast net used in marine waters in Pasuquin, Ilocos Norte Province. *Synonym:* Tabukol-baybay (Ilk.).

tabukol-panarayan (Iloko).—A cast net operated in rivers and inland bodies of water in Pasuquin, Ilocos Norte Province. *Synonym:* Tabukol-karayan (Ilk.).

tabukol-pang-ayungin (Iloko).—A cast net for taking ayungin (silver grunt).

tabukol-pangdalag (Iloko).—A cast net for taking dalag (murrel).

takib (Tagalog).—A sinamay filter net fished in river mouths for alamang (small shrimp). *Synonym:* Dayakos (Tag.).

takibo (Tagalog).—A drag seine designed with the bunt or landing portion made of staked split-bamboo matting, and with the winged portion functioning as an encircling drag net. The large enclosure is gradually reduced by drawing the whole length of the wings together until a small circular space is formed in the region of the matting. Here the catch is collected with a salakab (cover pot).

takilis (Tagalog).—A long, semicircular trap set in the shallow vegetation areas of Laguna de Bay. It consists of a series of staked fish corral mats joined end-to-end. These are gradually narrowed into a collecting chamber after men with poles have scared the fish from the vegetation. The catch is made with a salakab (Tag.) cover pot. In some places in Rizal Province, this term refers to a lift net (drive-in-net) operated with a submerged (weighted) scareline for taking gobies.

takis (Ilongo Bisaya).—A type of fish corral found in San Joaquin, Iloilo Province.

takit (Iloko; Ibanag).—A dip net used in Cagayan and Ilocos Provinces for taking ludong (mullet) during the upstream migration of the fish. *Synonym:* Takwit (Ilk.).

taklob (Ilongo Bisaya).—A split bamboo cover pot used in fishponds, creeks, and tide pools for catching fish, shrimp, and crabs. The split bamboo is tied to hoops that are graduated to produce a wide lower opening and a small upper opening.

taklob (Sebu Bisaya).—A small cast net operated in the swift-flowing, shallow rivers of northern Mindanao for catching gobies and sleepers.

tako (Iloko).—A dredge for catching snails in northern Luzon. Made of various non-textile materials, it is designed with a handle. Small sizes of this gear are operated by one man while wading, and larger ones are used from a boat.

taksay (Pilipino).—A small trawl net operated from an anchored banca in grounds where fish shelters have been set some days before. The ground is cleared of debris before the net is dragged. In Pangasinan Province, fish are either driven into the net, which is set against the current, or swept from the ground when the net is pulled to the banca. In Manila Bay no shelters are used, but the net is dragged along the grounds toward the banca by pulling the towing ropes attached to each wing. In Panay the term refers to a sinamay drag or beach seine.

takwit (Ibanag).—A dip net used in Cagayan Province for taking ludong (mullet) during their upstream migration. *Synonym:* Takit (Ilk.).

takyaw (Ibanag).—A round haul seine of cotton netting for catching schools of pelagic fish such as anchovies, sardines, and mackerel. It is fished with the aid of light during the dark of the moon. *Synonym:* Sapyaw (Pil.).

taga (Sambal).—A fish corral fished with receding water along swampy river banks and in inland lakes. It is provided with two long wings flanking a central collecting pound. *Synonym:* Pahibas (Tag.).

taga (Sebu Bisaya).—A fish spear used in northern Mindanao for catching sanga (devil ray). *Synonym:* Pangsanga (Seb. Bis.).

tagaban (Iloko).—An oval fish scoop of webbed bamboo for dipping shrimp from a rama (Ilk.), fish shelter.

tagabang (Iloko; Tagalog-Bikol).—A small fish corral built in the rivers of northern and southeastern Luzon, which is especially designed for catching shrimp.

tagad (Ilongo Bisaya).—A paddle-shaped iron or wood spade for digging diwal (mollusk).

tagara (Ibanag).—A small sinamay drag seine.

tagata (Bisaya).—A drag or beach seine.

tagon (Ilongo Bisaya).—A set handline, attended to periodically, for taking gobies in rivers. It may also designate a hookless, baited line for attracting crabs. In the latter case, a sigpaw (dip net) is used.

tagulanglang (Sebu Bisaya).—A beach or drag seine used in Loon, Bohol Province. A fish pot is used for the bag or pocket.

tain (Tagalog).—A cylindrical fish pot for catching fresh-water shrimp in Laguna and Tayabas Provinces. Measuring 1½ feet by 9 inches, it has an opening on each end, each guarded by a non-return valve. *Synonym:* Bubo-sa-hipon (Tag.).

taing (Tagalog).—A cylindrical fish pot used in Bataan Province. *Synonyms:* Tain or bubo-sa-hipon (Tag.).

talabog (Tagalog).—A group of about ten fish shelters for catching shrimp. These consist of coconut flower stalks made thicker by attaching debris, and the catch is made with a dip net. In some places in Rizal Province this term refers to a baited basket holding bunches of debris and left floating by anchoring it to a pole in the ground.

talakeb (Pangasinan).—A subcylindrical bamboo cover pot used to cover fish in muddy inland ground. This is sometimes used with light. *Synonym:* Salakab (Tag.).

talakob (Tagalog).—A purse seine operated from one or two fairly large (about 60 feet) rowing bancas. Now considered synonymous to kubkob (Bis.-Tag.), it referred originally to a two-boat purse seine, and the kubkob to a one-boat purse seine. *Synonyms:* Kubkob (Bis.-Tag.); talakop or panghasa-hasa (Tag.).

talakop (Tagalog).—A one- or two-boat purse seine for catching mackerel (hasa-hasa, alumahan). Literally, it means to enclose by two boats rowing in opposite directions, each forming an arc, until upon meeting they have described a complete circle. *Synonyms:* Talakob or panghasa-hasa (Tag.); kubkob (Bis.-Tag.).

talakop-sa-gilid (Tagalog).—A small purse seine used in the shallow water along the coast of Cavite Province. *Synonym:* Panggilid (Tag.).

talapang-de-balat (Pangasinan-Spanish).—A drag seine used in Alaminos, Pangasinan Province, for gathering balat (sea cucumber).

talik (Magindanaw).—A movable, shallow-water fish corral found in Dulawan, Cotabato Province, that resembles the tarik (Mag.).

tallakeb (Iloko).—A cylindrical bamboo cover pot. *Synonym:* Salakab (Tag.).

talunton (Bisaya).—A handline with two hooks attached to the line by a metal spreader.

tamang (Ibanag).—A small sinamay drag net for taking bangos fry in Cagayan Province. *Synonym:* Sagap (Bis.; Bat. Tag.).

tamba (Sebu Bisaya).—A trap net used in Bantayan, Cebu Province.

tambak (Bikol).—A river barricade with a collecting chamber made of split bamboo matting or of stones, such as those found in Camarines Sur and Tayabas Provinces.

tambak (Bisaya).—A fish shelter of twigs, branches, and leaves used in Sibuyan Island, Romblon Province. *Synonym:* Bumbon (Tag.).

tambog (Bisaya).—An encircling gill net used in Samar and Iloilo Provinces that is similar to the kayagkag (Bis.).

tambon (Ilongo Bisaya).—A fish shelter in seas and rivers for enticing varied species of fish. Capture is made by enclosing the spot with split bamboo matting.

tambong (Bikol).—A fish shelter used in Buhi, Bato, and Baao Lakes, Camarines Sur Province. Fish are impounded by bamboo matting, and after the debris inside the enclosure has been cleared, they are brailed out by dip nets. *Synonyms:* Bumbon (Tag.); arong (Bis.); rama (Ilk.).

taming (Sebu Bisaya).—A small, globular fish pot used in Cawayan, Leyte Province, for taking crabs, shrimp, and other small fish. Made with a circular opening on top, it is baited and then fished in rivers and lakes.

tampuli (Samar Bisaya).—A fish spear. *Synonym:* Bulos (Bik.).

tankob (Sebu Bisaya).—A small shallow-water fish corral built near river mouths or in small coves. It is designed with a leader and two wings converging into a large, heart-shaped enclosure. The latter leads into the collecting crib from which the catch is brailed out by dip nets. *Synonyms:* Bonuan-ordinaryo (Sam. Bis.); tangkop (Bis.).

tangab (Ilongo Bisaya).—A filter net used in Guimaras Strait, Iloilo Province, for catching small shrimp. Made of abaka twine with a sinamay cod end, it is set against the tidal current, both ebb and flood. Tagalog fishermen recently modernized this operation by using the tangab as the collecting portion of a fish corral made with staked, split bamboo matting but no leader.

tangkop (Bisaya).—A small, shallow fish corral used both in rivers and in the sea in Capiz, Negros, and Zamboanga Provinces. It is similar to the bonuan-ordinaryo (Sam. Bis.). *Synonym:* Tankob (Seb. Bis.).

tanggar (Iloko).—A filter net operated near river mouths for taking ipon. Made of sinamay and coarse cotton cloth, it is designed with two wings and a bag and is set to face the incoming tide by tying pull ropes to bamboo stakes. The catch is intermittently emptied from the bag. *Synonym:* Puket (Pang.; Ilk.).

tango (Iloko).—A tuck seine found in Bauan, La Union Province.

taon (Bisaya).—Ilongo and Aklan Bisaya generic term for different sizes of cylindrical or conical bamboo pots. These have circular, rectangular, or hexagonal openings guarded by a nonreturn valve in which the splints are tied parallel to each other over hoops.

taon-kinaban (Bisaya).—A slender, somewhat conical fish pot used baited in the sea, and fished unbaited when used as a collecting device in barricades, fishponds, or diked embankments. Its rectangular opening gradually tapers to a cone at the end.

taon-ligid (Bisaya).—A conical bamboo fish pot similar in every respect to the taon-kinaban (Bis.), except that it has a circular opening and a body tapering uniformly to the tip.

tapangan (Tagalog; Pangasinan; Sambal; Aklan Bisaya).—A baited cylindrical bamboo fish pot for catching crabs. The splints are matted in parallel series over hoops, with the two ends tapering slightly. Each end is provided with a circular opening guarded by a nonreturn valve. This gear is very similar to the kimpot (Kap.), except that the latter has only one valve.

tapsay (Bisaya; Maranaw).—A triangularly framed collapsible drive-in-net operated with a scareline. *Synonyms:* Konay or solambaw (Sam. Bis.).

tapsay (Iloko; Pangasinan).—A trawl net operated from an anchored banca. *Synonym:* Taksay (Pil.).

tarangutong (Iloko).—A fish shelter consisting of anchored debris of branches and twigs. After the shelter has been fenced with netting or bamboo matting and the debris cleared, the catch is brailed out by various devices, including cast nets. *Synonyms:* Bumbon (Tag.); rama (Ilk.).

tarapang (Iloko).—A fish spear used in Vintar, Ilocos Norte Province, for catching octopus, shrimp, eels, etc.

taraya (Moro; Bisaya).—A term for cast nets in all dialects of the non-Christians of Mindanao. *Synonym:* Dala (Tag.).

tarek (Iloko; Sambal).—A one-chambered shallow-water fish corral used in rice fields and dams for catching shrimp. It may or may not have a leader, but is designed with a filter net of sinamay for the collecting portion. When employed for catching varied species in rivers, its single chamber may be seined or a push net used in hauling in the catch. Sometimes fish shelters are set within the enclosure to entice fish.

tarek (Magindanaw).—A movable shallow-water fish corral in Cotabato Province. *Synonym:* Talik (Mag.).

tarek (Sambal).—A shallow-water fish corral built in rivers and rice fields. It is designed with a leader and two short wings converging into a heart-shaped enclosure. The latter leads into a crib that can be raised at will like a scoop.

tatasay (Iloko).—A trawl net operated from an anchored banca in Narvacan, Ilocos Sur Province. *Synonym:* Taksay (Pil.).

tatasay-tirong (Iloko).—A trawl net for submerged species in Santa Maria, Ilocos Sur Province.

taunton (Sebu Bisaya).—Handlines used in Bohol Province. *Synonym:* Talunton (Seb. Bis.).

taya (Iloko).—A barricade in Amburayan River. Made of sawali (webbed split bamboo) or cotton cloth, it employs bubos (fish pots) for the collecting portion.

tayog (Iloko).—A set lift net operated in rivers of Ilocos Norte Province by about eight men without the aid of a scareline.

teg (Iloko; Ibanag).—Dip nets used in northern Luzon for catching ludong (mullet) during their upstream migration.

telalakal (Kapampangan).—A fish trap for attracting hito (clariid catfish). It is composed of floating rings of banana sheaths baited with anay (white ants). The catch is made by throwing a cast net over the trap.

tellem (Iloko; Ibanag).—A small baited lift net for catching crabs. *Synonyms:* Sellem (Ilk.); bintol (Tag.).

tete (Samar Bisaya).—A pick for chipping off sisi (small species of oysters) from rocks in Samar Province. It is made with a chisel-like blade of metal and a 1½-foot wooden handle.

tikpaw (Ilongo Bisaya).—A light, cuplike dip net used in fishing with light from a boat. It is made of cotton netting and has a bamboo handle. With a whipping action, the fisherman lands crabs or fish that have been attracted to the light. *Synonym:* Tigpaw (Tag.).

tiksal (Tagalog).—A seven-pronged fish spear used in Laguna Province in fishing with a light from a banca. *Synonym:* Salapang (Tag.; Seb. Bis.).

tigaanan (Aklan Bisaya).—A pole and line.

tigbi (Ilongo Bisaya).—A drive-in-net operated with a long scareline. *Synonym:* Katigbi (Tag.).

tigpaw (Tagalog).—A dip net of fine cotton web or wire for catching crabs at night. About 1½-foot wide, it has a 9-foot handle, one end of which is a paddle. The fisherman at the bow paddles, scans the water for crabs, and suddenly whips the dip net into the water when he sights a crab. *Synonym:* Tikpaw (Il. Bis.).

tigsal (Tagalog).—A fish spear used in Laguna de Bay. Measuring 6 to 9 feet long, it has three to seven barbed blades and is fished from a banca with the aid of a light. *Synonyms:* Salapang or tiksal (Tag.); salubang (Ak. Bis.; Kuy).

tiid (Iloko).—A sinamay drag seine for catching ipon. It is similar to the daklis-de-ipon (Ilk.-Sp.), except that it has no bag.

tilay (Tagalog).—A handline or a drop line for catching kanduli (ariid catfish) in Laguna de Bay. Its distinctive features are the employment of live young kanduli for bait, and the use of a sharp-bottomed banca instead of the common flat type, in order to avoid disturbance of the water.

timing (Bisaya).—A four-cornered, globular rattan or bamboo fish pot for catching shrimp, crabs, and fish. It has a circular opening on top and is fished in rivers, swamps, fishponds, lakes, and shallow muddy water. It is baited with algae. *Synonyms:* Kiming (Kuy.); paniming (Seb. Bis.).

tinagala (Maranaw; Bisaya).—A deep-water fish corral devoid of collecting pounds. The catch is brailed out by a sigin (scoop seine). *Synonyms:* Paugmad or tinagala (Bis.); bunsod-lapad (Seb. Bis.); habog (Sam. Bis.).

tinagalog (Sebu Bisaya).—A deep-water fish corral in Surigao Province. It has no collecting pound, and the catch is taken from the semicircular enclosure by a sigin (scoop seine). *Synonyms:* Tinagalog (Mar.; Bis.); paugmad (Bis.).

tinumpang (Samar Bisaya).—An encircling gill net of cotton twine for catching gizzard shad. *Synonyms:* Banata (Sam. Bis.); ginantso (Bis.-Sp.).

tinures-pahubas (Samar Bisaya).—A shallow water fish corral that fishes during receding tide. It is similar to the pahubas, except that this gear is provided with a "tinures," meaning leader. *Synonym:* Pahutik (Sam. Bis.).

tipsay (Sebu Bisaya).—A drive-in-net. *Synonym:* Tapsay (Bis.).

tirador (Kuyonon-Spanish).—A fish spear in Palawan Island which is operated like a bow gun. It consists of an arrowlike barbed metal blade which is shot through a bamboo tube by a pair of elastics.

trapang (Iloko).—A two- or three-pronged fish spear for catching kurita (octopus).

tsintsoro (Pilipino-Spanish).—A drag or beach seine hauled to the shore or in shallow water. It is usually made of cotton netting with a bag. *Synonyms:* Pukot (Pil.); sinsoro (Pil.-Sp.).

tuad (Iloko).—A sinamay drag seine for catching ipon in La Union Province. It is similar to the daklis-de-ipon (Ilk.), except that it has no bag. *Synonym:* Tiid (Ilk.).

tubog (Batangas Tagalog).—A handline or drop line used in Batangas Province for still fishing.

tued (Iloko).—A sinamay drag seine for catching ipon. It is similar to the daklis-de-ipon, except that it has no bag. *Synonym:* Tuad (Ilk.).

tuel (Pangasinan).—A river fish corral which has a bamboo platform as the collecting portion. *Synonym:* Palukso (Tag.).

tulbong (Samar Bisaya).—A cast net used in Calbiga, Samar Province, for catching mullet. *Synonyms:* Dala (Tag.); laya-pamalanak (Sam. Bis.).

tulis (Bisaya).—A fish corral used in the Visayas. It consists of a leader and two wings converging into a series of three graduated, somewhat triangular compartments. These lead into the heart-shaped terminal pound.

tulokutok (Palanan).—A drive-in-net operated in Casiguran, Quezon Province, with the aid of a scareline. *Synonym:* Kulokutok (Tag.).

tumbok (Sebu Bisaya).—An encircling gill net used mainly for sardines. The fish are scared into gilling by wooden plungers. *Synonym:* Kayagkag (Bis.).

tunda (Samal).—Troll lines used in the Sulu Archipelago. *Synonyms:* Pahila and sibid-sibid (Tag.).

tungaltaw (Iloko).—This term applies to any of the following lines: When provided with a pole, it is a pole and line in which the only hook is floated; when a handline, it can be either an ordinary handline with a single hook, or it may be a multiple handline with not more than five snooded hooks attached to a floated mainline.

tungkob (Samal).—A shallow-water fish pot without floor or bottom.

tuwitang (Samal).—General term for longlines used in Jolo.

tunton (Aklan Bisaya).—General term for handlines in Panay Island.

tuyongan (Ivatan).—A handline, with one or two barbed hooks to a line, which is used in still fishing with a light.

tuyotuyan (Ivatan).—A small dip net for catching coral reef species in Batanes.

U

udaod (Iloko).—A drive-in-net operated generally with a submerged scareline, but sometimes with a floating scareline. Sometimes only the submerged scareline is used, and the catch then is effected by hand or by a cast net. *Synonym:* Ugnat (Tag.).

ugmad (Samar Bisaya).—A deep-water fish corral devoid of a collecting crib. The catch is taken direct from its semicircular enclosure with a sigin or gayad (scoop seine).

ugnat (Tagalog).—A rectangular drive-in-net for catching submerged fish such as gobies. It is floated on the corkline and leaded on the ground line. In Bulacan Province, this gear is especially designed for taking talimosak (long-tailed gobies). *Synonym:* Pang-ugnat (Tag.).

ulang-ulang (Sebu Bisaya; Samal).—A shrimp-shaped squid jig with one or two series of multiple barbless hooks at the "tail" region. *Synonyms:* Kawil-pangpusit (Tag.); lukon-lukon (Il. Bis.).

umang (Tagalog).—A small, heart-shaped, potlike trap for catching hito (clariid catfish). Made of split bamboo matting, it measures about 2 by 3 feet. *Synonyms:* Siid, bakikong or dakikong (Tag.).

unasan (Bisaya).—A stone barricade built on reefs for catching rock fish during ebbtide.

unay (Bisaya; Bikol).—A fish corral found in Escalante, Negros Occidental Province, and Albay Province.

unosin (Ivatan).—Troll lines. *Synonym:* Sibid-sibid (Pil.).

utase (Pilipino-Hapones).—A Japanese beam trawl for catching shrimp and submerged fish. It consists of a conical bag provided with two long wings of equal length. The mouth is kept open by a long detachable wooden beam and held upright by a brail attached to the end of each wing. Originally, this gear was operated from sailing vessels with six small trawls of manila twine drifted with the wind from the side. With the use of motor-propelled vessels, only one large trawl of cotton netting towed from the stern has been fished. This last has resulted in a more varied catch.

W

wangayan (Sebu Bisaya).—An inland-water fish corral in Agusan Province.

waswas (Sebu Bisaya).—A fish corral found in Jitafe, Bohol Province.

wisawisan (Iloko).—A pole and line, a simple handline, or a multiple handline. In Ilocos Norte Province, the multiple handline is provided with from five to nine snooded hooks attached to the leaded mainline, and it is commonly used in rivers.

Y

yako (Tagalog).—A dredge net for collecting snails in Laguna de Bay. *Synonyms:* Kaladkad or kulakod (Tag.).

yada (Banton Bisaya).—General term for cast nets in the Banton Bisaya-speaking regions of Romblon Province. *Synonym:* Dala (Tag.).

yagpit (Aklan Bisaya).—A one-bamboo-joint crab trap. Provided with a trap door controlled by a bow-and-trigger device, it is set at openings of crab burrows. *Synonyms:* Sarading (Kuy.); siklong (Pang.); lagpit (Il. Bis.); patibong (Tag.; Ban. Bis.).

yambo (Aklan Bisaya).—General term for troll lines. *Synonyms:* Pahila or sibid-sibid (Tag.).

yaya (Aklan Bisaya).—General term for cast nets in the Aklan regions of Panay Island. *Synonym:* Dala (Tag.).

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CURING OF FISHERY PRODUCTS

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RESEARCH REPORT 18

FISH AND WILDLIFE SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR

ABSTRACT

Fish curing is an important method of preservation in the fishing industry and in the trade generally, but information on the principles involved in the salting and smoking of fish commercially is widely scattered. This report is a reference handbook on the problems of fish curing. It includes information from recent technical studies of the principles on which fish curing is based, discusses improvements in methods and equipment, and describes the standard methods.

CURING OF FISHERY PRODUCTS

By NORMAN D. JARVIS, *Technologist*

March 3, 1849

RESEARCH REPORT 18

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United States Department of the Interior, Oscar L. Chapman, *Secretary*

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CONTENTS

Page
Importance of fish curing in the history of the United States........... 2
Statistical review of the fish curing industry........................... 6
Preservative action in fish curing.................................. 10
Air dried fishery products.. 13
Dehydration of fish... 32
Principles of fish salting.. 39
Dry salting cod... 44
Dry salt cod—foreign cures.. 63
Spoilage in dry salt cod and other cured fish....................... 73
Miscellaneous dry salt fish... 80
Dry salting fish in warm climates................................... 93
Miscellaneous brine-packed fish..................................... 99
Herring salting... 118
Salmon salting.. 133
Spiced and pickled fish... 146
Caviar and other fish roe products.................................. 164
Smoking fish.. 185
Herring smoking... 198
Salmon smoking.. 213
Smoked haddock and other groundfish................................. 223
Miscellaneous fish smoking.. 232
Delicatessen products... 254
Literature cited.. 260
Index... 267

CURING OF FISHERY PRODUCTS

Fish curing comprises all methods of preservation except refrigeration and canning. It includes (1) the drying, smoking, salting and pickling of fish, (2) various combinations of these methods, and (3) miscellaneous methods such as the use of vinegar and fermentation processes or ripening.[1]

The drying and smoking of fish are ancient processes. Archaeologists and anthropologists tell us that drying and smoking were probably developed shortly after the discovery of fire and before man learned to make pictographs on rocks. The art of salting is also very old, going back to the Stone Age. The use of vinegar and spices goes back, at least, to the Greeks and Romans. (Radcliffe 1921; Smidth 1873).

Fish curing has been an important factor in the development of all great maritime nations. From the Middle Ages until well into the nineteenth century agricultural methods were poor. Livestock were wintered with difficulty, and meat curing methods were so poor that there was little meat during the winter, also, other protein foods were scarce. Canning and freezing had not yet been developed. The people needed a fairly low-priced protein food which would remain in good condition for some time. Dried, salted, and smoked fish supplied this need. Before the beginning of the industrial age, international commerce was largely in natural products. The wine of Spain was exchanged for the dried and salt fish of England, the Netherlands, and Norway. The smoked herring of England was traded throughout central Europe. Even in the sixteenth century, when England was fighting Spain, her trade in dried fish with Spain was continued. It has been reported that England gained more wealth from cured-fish products in the sixteenth century than Spain obtained in gold from the Americas.

Despite the importance of fish curing since prehistoric times, information on methods of the industry is scattered and exact data are lacking. Great interest is exhibited in fish curing today, as it does not require the equipment or capital needed for canning or freezing. An individual with a little capital may dry, salt, or smoke fish, using only home-made equipment. Species of fish may be utilized that are not suitable for canning. Localities not adaptable to the operation of canning or freezing plants may be used for fish curing. During the years to come the whole world will need all available sources of protein. Dried and salt fish are not only good sources of protein but may be produced at a lower cost than other animal protein foods. Statistical data given elsewhere in this report show that fish curing makes up the greatest volume of fishery products in every country in the world having important fisheries, excepting the United States and Canada. In the latter country, cured and canned products are approximately equal in amount.

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[1] The material contained in this publication could not have been presented without the cordial assistance of numerous persons in the fish-curing industry, fishery officials of several States and countries and others interested in fisheries. Special mention is due C. L. Anderson, Dr. M. Besnard, D. L. Cooper, Dewitt Gilbert, Katherine Howe, O. Notevarp, G. A. Reay, Michel Vucassovich, Food Industries, and the Pacific Fisherman. The author also desires to acknowledge his appreciation for information, illustrations and other assistance given by various individuals and firms too numerous to list individually. Specific acknowledgment of the source of illustrative material is made at the point of insertion. The British Ministry of Food photographs were supplied by the Torry Research Station of the Department of Scientific and Industrial Research and are reproduced with the permission of the Controller of His Britannic Majesty's Stationery Office.

Technical studies of the principles on which fish curing is based, and on improvements in methods and equipment together with descriptions of standard methods have been made from time to time. Some of the publications are unavailable for reference, and the work has not been integrated as a whole. The Fish and Wildlife Service receives a large number of requests from individuals, commercial firms, and official agencies, both here and abroad for up-to-date information on the technology of fish curing. This situation emphasizes the need for a reference handbook on commercial curing of fishery products. This report is intended to supply that need.

IMPORTANCE OF FISH CURING IN THE HISTORY OF THE UNITED STATES

ATLANTIC COAST

The fish-curing industry of the North Atlantic coast of North America dates back at least to the year 1500. There are authentic records of fish-curing activities as of that period, and legends of activities at much earlier date. An extensive fish-curing industry along the North Atlantic coast of North America was carried on for more than one hundred years before there was any permanent settlement. As early as the year 1580 more than 300 ships from Europe were salting cod in this area. Newfoundland, "the oldest British colony," owes its origin to the fish-curing industry which is still the dominant factor in the economic life of that country.

The early colonists in New England and the Maritime Provinces would not have been able to survive without the salt cod and smoked herring they could prepare, for soil was poor and the climate uncertain. While fish meant food to the early colonists, cured fish soon became their capital resource and their stock in trade for the purchase of supplies. Their most abundant fish, cod, could be manufactured into a durable protein food product, withstanding the primitive shipping and storage conditions of the day, and was comparatively low in price. Other cured fish such as smoked halibut and herring, pickled sturgeon, and salt salmon were soon being shipped abroad. Out of this grew the "triangular trade": salt fish to Europe, manufactured goods from Europe to the West Indies, and sugar, rum, and molasses to New England. The trade in salt fish stimulated other industries and capital was gradually accumulated so that the colonists could go into shipping. Later, other natural resources such as timber were exploited, and the first attempts were made to create other local manufactures.

The importance of fish curing in the development of trade and industry in early New England is discussed at some length by Ackerman (1941) who describes how various New England industries owe their origin to the foreign trade in cured fish.

The fish-curing industry continued to grow and prosper, dominating the economic life of the New England colonies in the late 17th and 18th centuries. The French government was also concerned. It was attempting to expand the fisheries in the northwestern Atlantic in order to build up a large fish-curing industry in its colony in Canada. Both the British and French attempted to dominate as much of the North American fishing grounds as possible, in order to secure the trade in salted and dried fish for themselves. Attempts were made to establish boundaries, but they were poorly defined, so that the fishing rights over a wide area were the cause of frequent bickering, sometimes flaring up into undeclared warfare. Indeed, the series of wars between France and England were in part due to disputes over fishing grounds and fish-curing locations. The fishermen and fish curers of New England and Nova Scotia played an important part in England's conquest of Canada, for to them the fishing rights meant life or death.

The disputes did not end with the ousting of France from Canada, but continued with the new England colonists, on the one hand, and the English, on the other. Parliament passed a bill in 1775 which prohibited the New England colonies from trading directly with foreign countries and prevented New England vessels from fishing on the banks of Newfoundland, in the Gulf of St. Lawrence, and on the coasts of Labrador and Nova Scotia where they had been accustomed to go. This meant ruin to the New England fish-curing industry, and the edict was one of the leading causes of bringing the New England colonies into the Revolutionary War.

The treaty of peace negotiated in 1783 was delayed by the insistence of the American delegates on securing favorable fishery rights. They regarded these so important that they refused to sign a general treaty of peace, leaving the fishing rights for later adjudication. The British proposed to exclude the New England fish-curing industry from grounds and areas where New Englanders had fished and cured fish extensively as colonists. Finally, however, the American delegation was able to obtain a treaty article on fisheries which granted favorable conditions to the United States.

The New England fish-curing industry generally prospered under the new Republic, taking salt-cod markets in southern Europe and the Mediterranean from the British and Scandinavians. Disputes arose with Great Britain over trade, the interpretation of fishery rights, and the impressment of American fishermen and seamen into the Royal Navy. Restrictions and embargoes were imposed by both Great Britain and the United States, resulting in a decline in the salt-fish industry after 1807. The War of 1812 almost ruined the industry. The war was so unpopular among shipping, commercial, and fish-curing groups that there was a move toward secession in some of the New England States.

At the end of the War of 1812 the British claimed that the war abrogated the treaty of 1783. The United States claimed that this treaty was still valid. Seizures of American fishing vessels were made and it seemed for a time that a new war might break out. Tension was eased by the signing of a new fishery convention in 1818. It was followed, however, by a whole series of disputes on interpretation, at times resulting in severe diplomatic tension. The rights involved in our fish-curing industry in the northeastern Atlantic off the coasts of Canada and Newfoundland were probably the most important single cause of disagreement during most of the nineteenth century between the United States on the one hand, and Great Britain, with the Dominion of Canada, on the other.

Trouble occurred more infrequently and was of less intensity in the last decades of the 19th century, as refrigeration developed and a wider market was created in the United States for fresh fish, making salting and drying of fish on the northeastern coast less important. It was also possible to conduct all operations at sea away from the coast. While the feeling was not so intense, the points of difference in interpretation of the Convention of 1818 remained unsettled and it was decided to submit the points at issue to arbitration under the Hague Convention. A decision was rendered in 1910. Since that time the only fisheries disputes between the United States, Great Britain, Newfoundland, and the Dominion of Canada, have concerned the duties to be levied on fishery products under our tariff acts. The U. S. Tariff Commission in Report No. 152 gives a complete account of the fishery question on the northeastern Atlantic coast, together with the various treaties and other agreements on the fisheries.

PACIFIC COAST

The fisheries on the Pacific coast of North America have not affected our international relations to the same extent as the fisheries of the Atlantic. This is (1) because their development is much more recent and (2) the development has been different in character. The second factor is possibly due to the fact that development occurred at a period when canning and refrigeration were replacing curing as the principal methods of preservation. Then, too, more of the fishing takes place in clearly defined territorial waters.

There have been a number of disputes between Canada and the United States over Pacific fishery problems but they have been minor in character when compared with those in the Atlantic, and none has concerned fish curing. In the 1930's, Japan invaded fishing grounds off the coast of Alaska, and interfered with our vessels which were catching and salting cod. The cod fishermen threatened to shoot any Japanese obstructing their operations. Japanese fishing was a matter of great concern to the Pacific coast fisherman, but little notice was taken nationally until it was proved that the Japanese were catching salmon despite an undertaking to the contrary. The controversy was still unsettled when Japan went to war with the United States. The fishery dispute may be regarded as a contributory, though minor, cause leading to war with Japan.

Cured fish of various types were the first manufactured products prepared on the Pacific coast. The Indians had a considerable dried-salmon industry at The Dalles, on the Columbia River, long before the coming of the white man. The fish were traded to the plains tribes of the interior. The Indians still dry small amounts of salmon at The Dalles for their own use. According to Cobb (1930) the Russians operated a commercial salt-salmon industry in Alaska at the beginning of the 19th century. Salt salmon was shipped as far as St. Petersburg. Soon afterward the Northwest Fur Company started a salmon-salting business on the Columbia River. The Northwest Company merged with the Hudson's Bay Company which shipped salt salmon to Hawaii, Australia, China, Japan, and the eastern United States. American fishermen salted salmon in Alaska while it was still a Russian possession. A number of the large salmon canneries of today were originally established as salmon salteries.

The presence of cod off the coast of Alaska was established in the 1860's and the possibility of building a prosperous salt-cod industry there was one of the arguments advanced in Congress for the purchase of Alaska. More recent but still incomplete studies have established that the Pacific banks are larger and of greater potential production than the Grand Banks off the coast of Newfoundland. Yet, utilization today is less than it was 30 years ago.

During World War II the Pacific coast fish-curing industry was much more adversely affected than that on the Atlantic coast. When the Alaskan area became a combat zone, almost all fishing and fish-curing activities were stopped. All but one of the cod-salting vessels was requisitioned by the Government. Herring salting in southeastern Alaska was almost impossible because of the great increase in costs, the scarcity of labor, and the necessity of using commercial vessels for war purposes. These causes also adversely affected the mild curing of salmon. The loss of foreign markets and the effect of pricing regulations were other unfavorable factors. It is expected that there will be some recovery of the Pacific coast fish-curing industry in the postwar period, but anything approaching a restoration of the prewar trade will require the development of specialty products and a reduction in the cost of production.

STATISTICAL REVIEW OF THE FISH CURING INDUSTRY

Complete statistical data on the production of cured fish in the United States over the last 60 years, or any consecutive series of years within the period, are lacking. This is unfortunate as both canning and refrigeration industries were being developed during this period; in fact many changes were taking place in food habits and food products, with great effect on the fishing industry.

The first production figures available on the fish-curing industry are reported by Goode (1884), but the data do not cover the entire United States and are reasonably complete only for the New England States. The first complete figures on manufactured fishery products are for 1908. It is the first reasonably complete and accurate statistical record on the production of cured fish in the United States. In 1908 the total production amounted to 187,299,000 pounds with a value to the producer of $11,018,000. In 1940 production decreased to 97,439,000 pounds, but the value increased to $14,235,000. The decline in the production of salt groundfish is even more startling if the New England area, historically the most important, is considered separately. This is shown graphically in figure 1. From 79,009,000 pounds in 1880 the production fell to 4,742,000 pounds in 1919.

In 1908, dried and salted groundfish (cod, haddock, cusk, hake, and pollock) totaled 84,642,000 pounds while in 1940 it was 17,697,000 pounds. It is believed that a portion of the boneless salt cod reported in 1940 was prepared from green-salted fish imported from Canada and is, therefore, not entirely a product of the United States fisheries. Pickled or hard-salt salmon amounted to 14,595,000 pounds in 1908 while in 1940 it was 829,000 pounds. The production of mild-cured salmon showed little change since it equalled 8,483,000 pounds in 1908 and 7,770,000 pounds in 1940. Incidentally, 1940 was a war year, and foreign markets which usually absorbed an important share of the production had been eliminated. More than 1,200,000 pounds of halibut were smoked in 1908, while only a few hundred pounds were prepared in 1940. Production of smoked herring was 13,311,000

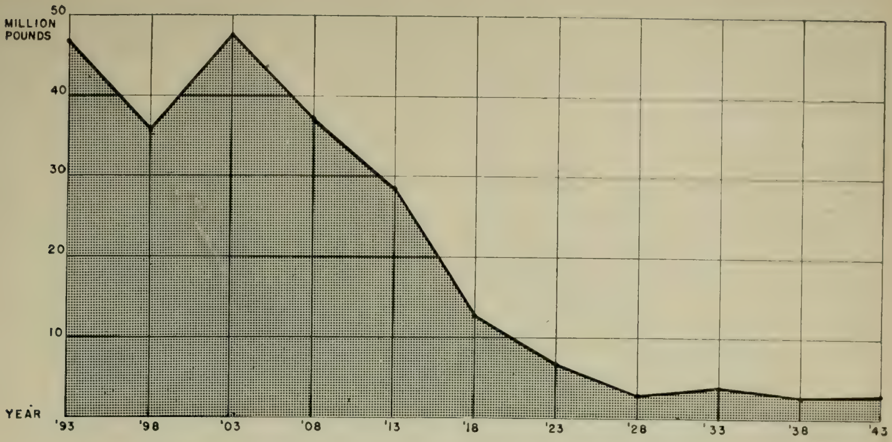

Figure 1.—Landings of salt groundfish, New England, 1893–1943.

pounds in 1908 but it totaled only 3,629,000 pounds in 1940. On the other hand, no smoked kippered sablefish was prepared in 1908 while there was a production of 1,176,000 pounds in 1940. The production of dried shrimp is given as 342,000 pounds in 1908 and 2,069,000 pounds in 1940. Herring pickled in vinegar and spiced herring were not reported in 1908, while production of these two items totaled 3,537,000 pounds in 1940. This is believed to involve some duplication as herring pickled in vinegar is used in the production of spiced herring. Kippered salmon is not reported in 1908 while 2,543,000 pounds were produced in 1940. Production of smoked salmon amounted to 4,297,000 pounds in 1908 and it was 8,423,000 pounds in 1940. No smoked

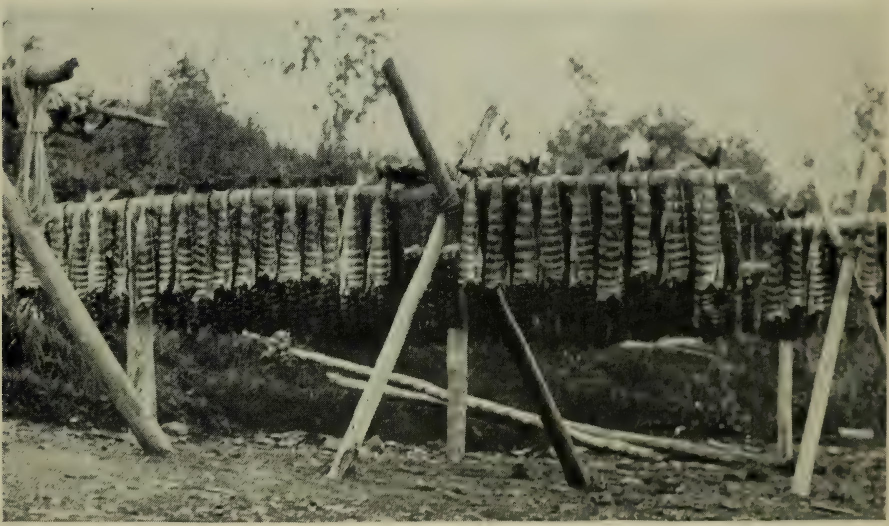

Figure 2.—Air-drying salmon, Alaska.

buffalofish, butterfish, or carp are listed in 1908, while production of these three items totaled 1,004,000 pounds in 1940.

In 1908 cured fishery products represented 42 percent of the manufactured fishery products while canned fish and sea foods amounted to 57 percent (Census 1911). In 1940 production of cured fishery products amounted to 97,439,000 pounds with a value to the primary producer of $14,235,000 while production of canned products amounted to 708,930,000 pounds with a value of $94,182,000. Thus in 1940, cured fish accounted for 9 percent of the quantity and 10 percent of the value.

The fish-curing industry is much more important in other countries with large fishery industries, than in the United States, and fish curing in these countries does not show a decrease to the same extent as in the United States. Japan was the world's largest producer of cured fishery products at the outbreak of World War II. In 1936, the most recent year for which statistics are available, Japanese data show a production of 1,234,709,000 pounds of cured-fishery products with a value of $49,609,000. The production of canned fish amounted to 223,899,000 pounds, with a value of $20,318,000. It is understood that cured products were prepared largely for home consumption, and the greater portion of the canned products was exported. Fish paste was the most important single item, with a production of 203,856,000 pounds. Seaweed prepared by several different methods is also an important cured product in Japan. The only method of curing not greatly favored in Japan is smoking. The total amount cured by this method was only 1,847,000 pounds.

The production of cured fishery products in Canada is greater than in the United States but the value to the producer is less. The total of cured products in 1938, the last year of normal prewar production, amounted to 125,451,000 pounds with a value of $4,250,000. Difference in value of production is believed due to the fact that items produced in Canada are largely the standard low-priced products, while the United States prepares more high-priced cured fish specialities. For instance, in Canada the total production of smoked and kippered salmon in 1938 is reported as 26,000 pounds with a value of $3,000, while the United States production of smoked and kippered salmon in 1940 was 10,966,000 pounds with a value of $3,563,000. Canadian statistics do not show any production of such articles as smoked sturgeon and spiced herring.

Causes of Decline in Fish Curing In the United States

The decline in production of cured fishery products cannot be ascribed to any one cause. An important factor is the development of better methods of preservation, such as canning and freezing. Not only has the consuming public come to prefer canned and frozen fishery products rather than cured, but the industries based on these products took raw material formerly utilized in fish curing. As an example, haddock was in little use in the fresh-fish market of the 19th century but appeared almost entirely as a dried-salted or smoked product. The New England States prepared 6,510,000 pounds of boneless and dry-salted haddock in 1908, but only 13,000 pounds in 1940. No fresh or frozen haddock fillets are reported in 1908 but 36,597,000 pounds are reported for 1940. The development of the fillet industry practically eliminated the curing of haddock, but the total consumption of haddock has greatly increased.

The new methods, canning and freezing, resulted in a more marketable product and in the case of canning at least, a greater length of preservation. Cured fish was the most durable preserved protein food available until the latter part of the 19th century, but admittedly when prepared for the table it does not resemble fresh fish as closely as canned fish does. It is subject to deterioration by reddening, molds, and other types of spoilage to which canned products are immune, and does not offer the variety available in canned fishery products.

Cured fish, as prepared in large-scale production, is not so economically practicable as canned or frozen packaged products. The percentage of loss in preparation is much greater so that raw material costs per unit of consumption are higher for cured products. The curer, therefore, cannot afford to pay as much for raw material. Fish curing to date involves a great deal of hand labor and except to a limited extent, in Norway and Germany, has not been mechanized while canning has been highly mechanized. Fish curing is, therefore, unprofitable when labor and raw material costs are high. Cost of production adversely affected the United States fish-curing industry earlier and to a greater extent than that in Newfoundland, Iceland, Norway, and Canada. This country was forced to abandon foreign trade in cured groundfish after the first World War, but the decline was evident even before this. Later, even the domestic trade became unprofitable.

The most pronounced trend in the food industry has been toward the consumer-size package, and there has been much improvement in packaging. Fish-curing methods are essentially those of 60 years ago. Much of the cured fish is handled in pails, barrels, or in bulk. Therefore, most cured fish are not attractive for the retailer to handle.

Another factor in the decline of fish curing is the change in food habits. European immigrants were accustomed to cured fishery products and introduced many different cured-fish articles to this country, but their children developed other food habits.

Prospects for Increasing Consumption

Curing cannot be expected to regain its place as the principal method for the preservation of fish and seafoods, but the situation is not so dark as the preceding discussion would seem to indicate. The trade in cured fishery products can be increased. In the first place, there must be a standardization of quality. There is too wide a variation in quality between the products of individual producers and day-to-day production. Improvement requires careful study of methods used and the development of controlled techniques.

The packaging of cured fishery products should be given the same careful study as the packaging of fresh and frozen foods. Some progress had been made prior to World War II by individual firms. While this work was limited in scope, and results are not sufficiently clear to warrant positive conclusions, it is indicated that proper packaging is a tremendous aid in selling and would make cured fish more attractive to the retail dealer and consumer.

A well-prepared and consistent educational program carried on over a period of years, spreading knowledge of the principles of food preservation and advocating techniques developed through systematic experimental work, would acquaint the general public with the superior appetite appeal and nutritive value of well-prepared, cured fishery products. This program should include demonstrations on cookery and preparation for the table, which has almost become a lost art. The industry is now realizing that spreading information on fresh-fish cookery has been neglected, with a consequent effect on demand. This is even more true with cured fish.

It is also believed that a variety of specialty items rather than a few old-time standard articles would increase sales. These items can generally be sold at higher prices so that labor and raw material costs are not a production obstacle. An example of this is the increased production and demand for smoked salmon. The demand for the various spiced-herring specialties is also increasing. Smoked oysters, shrimp, and crab meat are new cured-fish specialties in excellent demand. Many specialties are described in this report and from the information given here it should be possible to develop others.

PRESERVATIVE ACTION IN FISH CURING

Food preservation attempts to prevent or inhibit deterioration or spoilage of the food material for as long a period of time as possible. The agents causing spoilage may be present in the raw material when it is obtained; they may be introduced later during the process of manufacture or preservation, or during the storage period. There are two general types of deterioration: (1) that due to microbiological action, and (2) changes as a result of chemical or physical action. Micro-organisms are responsible for by far the greater amount of food spoilage.

SPOILAGE ORGANISMS

The number of types of spoilage organisms which may be involved in the deterioration of cured fishery products is almost infinite. They may be divided into three general classes: (1) molds, (2) yeasts, and (3) bacteria. In canning products, heat-resistant spore-forming bacteria are almost entirely responsible for any spoilage which occurs. The ordinary heat treatment given in canning is sufficient to render impotent all yeasts, molds, and ordinary types of bacteria.

Molds

Molds are fungi which are distinguished from micro-organisms by the formation of mycelia, which are networks of filaments or threads. These threads or hyphae are usually visible to the naked eye. Molds as a group are mostly aerobic, preferring a slightly acid media, and can tolerate higher acidity and osmotic pressure than can bacteria. Molds in general require less moisture than bacteria. They are essentially surface growers, though the hyphae will soon penetrate throughout the whole flesh structure. The mold spores are much better adapted to air dispersal than bacteria, and, therefore, there is more danger of contamination of smoked or dried fish. The two groups of molds most likely to cause trouble in cured fishery products are species of *Penicillium* and *Aspergillus*. For more adequate information the reader should consult Tanner (1944) or any other good text on microbiology.

Yeasts

Yeasts are characterized as fungi which multiply by budding or fission or a combination of these two processes. They may also reproduce by intracellular spore formation whereby each cell may develop into an ascus containing several ascospores. Yeasts are generally aerobic. They usually require some sugar. Yeasts, while of great importance in certain food industries are of minor importance in fish curing. They may be found in some types of spiced-fish products, and the preservation of certain cured fishery products in the Orient such as fish in rice paste is due to fermentation by yeast.

Bacteria

Bacteria are unicellular organisms which reproduce by simple binary fission. Bacterial cells may be divided into three basic groups or shapes: the cocci or spheres, the bacilli or straight rods, and the spirilla or curved rod forms. According to Cruess (1938), the grouping should include practically all the fission fungi. The deterioration or spoilage of fish flesh is particularly due to bacteria. Fish flesh is especially susceptible to both bacterial and enzymatic decomposition, so that the problems of preservation are particularly acute. Bacteriologists have given considerable attention to the microbiology of fish. Tanner (1944) gives a summary of their findings.

Optimum Conditions for Micro-organisms

Micro-organisms require moisture and a favorable temperature for development because they can utilize only liquid food which is absorbed through the cell wall. A moisture content of less than 35 percent has a direct inhibiting effect. The most favorable temperature for the development of ordinary forms of bacteria is between 70° and 100° F. Microbiological activity is greatly reduced at temperatures around 32° F. and growth of bacteria is practically inhibited at 0° F. Most organisms grow best in an alkaline or neutral medium so acids have an inhibiting effect. The addition of acids to inhibit bacteria is the basis of the preparation of vinegar-cured fish. Preservation in this case is temporary, however, since a vinegar solution in excess of 5 percent acidity (as acetic acid) will make the product unpalatable. A 15-percent solution is required to absolutely inhibit bacterial activity.

The food must be liquefied so that the micro-organisms can absorb the nutrients necessary for growth. The micro-organisms present secrete an exoenzyme which breaks down the substrate into products that can be absorbed through their body walls. Waste products resulting from this absorption are excreted through the cell walls, thus furnishing such distinguishing characteristics of decomposition as "off" odors and tissue break-down. Putrefaction results from the anaerobic decomposition of the flesh.

Autolysis

The cells in flesh tissue also contain enzymes which do not cease their activity upon the death of the animal, and may digest the cells in which they are contained. This process is known as "autolysis" or self-digestion and is distinct from putrefaction as described in the preceding paragraph. Autolysis is especially marked in species which have been feeding when caught, then death prevents completion of the normal cycle of digestion. The larger quantities of digestive enzymes manufactured during the feeding process are prevented from fulfilling their function of preparing food for absorption. They therefore attack the walls of the digestive tract which are destroyed with extreme rapidity. The enzymes then pass to the flesh which is also softened in a short time. This process is normal and the flesh is not absolutely inedible but it is unsuitable as raw material for curing due to the extreme softness of texture and the "off" flavors developed.

A good example of autolysis, for the purpose of illustration, is that in "feedy" salmon. Troll-caught salmon must be eviscerated immediately after catching and packed in crushed ice. If this is not done they will be found unfit for use in a very few hours. The flesh becomes soft and flabby, the abdominal surface to such a degree that the bones protrude. Though the flesh is not putrefied it may show many breaks and is difficult to handle in mild curing. The cured product is objectionable in appearance, color, flavor, odor, and texture. Deterioration of Atlantic mackerel occurs even more rapidly than salmon.

AIR-DRIED FISHERY PRODUCTS

PRINCIPLES OF FISH DRYING

The two factors necessary for bacterial growth are heat and moisture. Of these, moisture is the more important, for if there is sufficient moisture bacterial growth can occur at temperatures near freezing, while if the moisture content is reduced to a low point, bacterial growth is inhibited for long periods. There are several methods used in the fish curing industry for the removal of moisture such as exposure to the open air, pressure, use of absorption pads, application of the principle of osmosis as in covering the fish with salt, the use of heat, and combinations of these methods. In curing cod, part of the moisture is removed by salt, part by pressing, and part by exposure to the open air.

The only method of fish curing that can be considered as drying in the strict sense is natural air drying or in mechanical driers. Removal of moisture by salt is through osmosis, smoke acts as a chemical preservative as well as a drying agent, and pressure forces out moisture. Dehydration is differentiated from drying in that the product is much less like fresh fish than the naturally dried product, moisture content is reduced to a lower point, the form is changed, and the method depends on successful mechanical control of heat and moisture.

Natural air drying is the oldest method of food preservation. It was used by the ancient Egyptians, and, it is believed, long before them by the most primitive tribes of the early stone age. Air drying requires either a warm climate with low humidity, or, if the climate is cold, a good breeze and low humidity. It is used extensively commercially in Norway and in the Orient, especially in India, China, Japan, and the Philippines. While the climate of the United States is not particularly suitable for air drying, it is used for curing a variety of products in this country. Of these, shrimp is the most important commercial commodity. A large amount of salmon is cured by air drying in Alaska, principally as winter food for the natives and their dogs.

Halibut Rackling

This is a product prepared largely on the north Pacific coast of the United States and in Alaska. It was introduced in the United States by Scandinavian fishermen, who prepare it mostly for home use. It is a well-known commercial product in Norway, where it is a prominent product of the Bergen fish market.

Rackling is prepared principally from halibut on the Pacific coast, but large flounder or rock cod, or similar fish with a fat content of about two percent are suitable. The fish are headed and cleaned, leaving the collarbone or napes. After removing the viscera the fish are split into two sides, removing the backbone. The sides are cut in long narrow strips about an inch wide which are left joined together at the collarbone. The pieces are washed very thoroughly. All traces of blood must be removed or the product will be inferior when dried.

After draining, the strips are soaked in a 95° salt brine (one that will float a potato) for one or two hours. The fish are then hung out to dry where they will be exposed to as much breeze as possible, preferably in a shady place where they will not be exposed to direct sunlight. Often, however, the strips of fish are hung out to dry in the rigging of fishing vessels.

Drying requires from one to two weeks. Rackling is most often eaten like jerked meat without any preliminary preparation. It may be prepared for use by soaking for a few hours to rehydrate, then it may be steamed or boiled, and made into various dishes such as fish cakes, fish loaf, or creamed fish.

SALMON

The air drying of salmon is an important method of preservation in Alaska. It is used mostly by Indians. Drying is carried on most extensively in the interior, especially along the Yukon, Kuskokwim, Tanana and Copper Rivers, but it is also followed all along the coast of Alaska. Dried salmon is a staple winter food for the natives of Alaska, especially for their dogs. A sledge dog is reported to require 10 pounds of dried salmon per day in winter when in harness. White fish and grayling are also dried by the same method in the interior, and cod, halibut, and large flounder along the coast. Statistical data indicate a production of 2,000,000 pounds of dried salmon in 1940 (Fiedler 1943). Since much of the production is at scattered and isolated spots, the amount may have been larger.

The salmon taken for drying are caught principally by fish wheels along the interior streams. The apparatus and method are described in detail by Cobb (1930). Along the coast, stake gill nets are used extensively. Some salmon are taken for drying by haul seines, both on the coast and in the interior. In rivers of the Bering Sea area, salmon are caught for drying by means of wickerwork traps constructed on the principle of the fyke net. These traps are made of a series of cylindrical and conical baskets, fitting into each other with a small opening in the end connecting one with the other, the series ending in a tube with a door in the bottom through which the catch is removed. The work of preparing dried salmon is performed mostly by women.

Good fish curers break the backbone just back of the head as soon as the salmon are caught. This is done to bleed the fish, and also to kill them at once, preventing thrashing about and bruising the flesh. The butchering or cleaning process is as follows: The heads are cut or broken off, leaving the collarbone or nape. A knife is inserted at the collarbone just above the backbone and is drawn along the backbone to within two or three inches of the tail. A similar cut is made just under the backbone, which is then broken off close to the tail. The salmon are now divided into two halves except for the small section near the tail where they remain joined. The viscera, membranes, and other offal are scraped out, and the fish are washed roughly, in sea water, if along the coast. A series of transverse cuts, about three or four inches apart, is made to facilitate drying.

The fish are then hung from poles on a drying frame (fig 2). They are hung flesh side out, with one side on each side of the pole. Sometimes when poles cannot be obtained for a drying rack, the two sides of the fish are separated and laid flesh side up on a gravel beach. The salmon do not dry so well when this is done.

The salmon remain on the rack until thoroughly dried. Sometimes in rainy or foggy weather the fish are taken down and placed under shelter, but as a rule they are left on the racks with the skin turned outward. When the fish are of average size the drying process requires from 10 days to 2 weeks in ordinary weather. More time is required if drying conditions are not good, or if the salmon are large. The location of the drying racks is important. They should be placed on a headland or in an open space on dry ground where there is a good sweep of breeze. On still days, a smudge of green wood is sometimes used to keep the flies away.

When the drying process is completed, the dried salmon are stored in a cool, dry place, out of the reach of children and dogs. The storehouse is often built on a platform elevated 10 to 12 feet from the ground and is the so-called cache of Alaskan stories.

SHARKS, SKATES, AND RAYS

Shark meat is dried for food in numerous parts of the world where these fish are taken in quantity. Various species of the shark family are probably the most abundant source of raw material for fish curing on the Pacific coast of South America. These fish are dried commercially on the northern section of the coast of Peru. Skates and rays are also dried on a fairly extensive scale. With considerable development taking place in the fisheries of Peru, it is expected that production will be increased.

For a tropical area the Pacific coast of South America has unusually favorable conditions for fish drying. This is because the climate is very dry, the temperature moderate, and there is a regular breeze in many sections. The principal handicaps to date have been lack of fishing craft, poor transportation facilities, and unorganized marketing. The information given here was gathered on a survey made during 1941, at the request of the Peruvian Government (Fiedler, Jarvis, and Lobell 1943).

Sharks and rays (Elasmobranchii) are dried, such as "angelotes" (angel shark, *Squatina squatina*), "tollos" (dogfish or small sharks), "cazons" (large sharks of several varieties, none of which were identified as to species), and "rayas" (several species of Rajidae).

When the fish have been landed on the beach they are divided into individual shares and each fisherman sets to work on his own pile of fish with a home-made sheath knife.

In butchering angelotes, tollos, and cazons, the fins are cut away, then a first cut is made, splitting the fish; a second cut opens up the right side; while two or three more cuts open up the left side. The head is then cut away, viscera removed, and the flesh is scored, for rapidity in curing. Butchering is done very rapidly and skillfully. The fish are buried in the sand as they are butchered.

The dressed fish are taken down into the salt water, usually by the fishermen's children, who wash the fish and free them from blood, bits of viscera, sand, or other waste material. Two or three thin pieces of cane are inserted into the flesh crosswise, to hold the fish open, and they are hung on pole racks and left to dry in the open air. Drying requires about one week, although it may be finished in four or five days if the fish are small or weather conditions are unusually favorable. No salt or other curing agent is used, preservation depending entirely on air-drying. The cured fish are known locally as "bacalao" and resemble stockfish in general appearance but are somewhat thinner.

Skates or rays are prepared as follows: After laying the fish on its back, two circular cuts are made down the ventral side. The first slices away the lower wall of the mouth and gill cavity, leaving this wall hanging as a flap on the left side anteriorly. The second cuts away the lower wall of the abdominal cavity, leaving this as a flap on the left side posteriorly. The entrails are then removed; a vertical cut from above is made through the backbone from the head to the base of the tail and one or two short slashes may be made on each side of the thick base of the tail. A series of cuts are then made across the disk of the ray, which now looks like a circular gridiron. These slashes penetrate to the skin below.

After the rays are all butchered, sand is rubbed well into each cut and the fish are laid in a hole in the beach. The hole is covered by straw mats or by a layer of sand. The moist sand absorbs the blood, and the fish are removed after about 24 hours. They are then washed in the surf, drained, and a small amount of coarse salt (half ground) is rubbed into the flesh, after which they are hung across pole racks to dry in the open air. Four or five days are required for drying. This dried fish is said to remain in good condition from two to six months, depending on size, care taken in drying, and storage conditions while held for sale.

SHARK FINS

Shark fins are used extensively for food in the Orient, particularly by the Chinese. They are cured in the Philippine Islands, China and other Asiatic lands, the islands of the South Pacific, the West Indies, South America, Southern California, and Mexico. The United States production of dried shark fins is given as 24,000 pounds in 1940.

While the soupfin shark is taken extensively, it is used principally as a source of vitamin oils. The fins are only a byproduct and are sometimes wasted in this fishery. Any variety of shark will supply suitable raw material, provided the fins are large enough. They should be at least six inches in length, otherwise they are too small to have any substance. The best sizes are from 8 to 12 or 14 inches. The dorsal fin is preferred for drying, but the pectoral and anal fins are also used. The caudal fin is considered worthless.

The fins must be properly trimmed and cured to make an acceptable product. They are cut off at the joint connecting the fin with the body. All fleshy parts must be trimmed away, leaving only the true fin with its rays, as the cartilaginous material of the rays is the only part valued as food. After trimming and washing, the rays are spread on low bamboo or wickerwork frames, or flakes, to dry in the sun. The fins are turned from time to time. No salt or other preservative is used, though some of the curers dust the cut surface of the fin with lime. From two to three weeks are required for drying. The fins are usually brought into a dry shelter at night.

When dry they are packed in cases or barrels of about 250 pounds each or in gunny sacks holding from 150 to 200 pounds. The average wholesale market price is 65 to 75 cents a pound for choice fins. In normal times about five tons per month are handled at San Francisco, where they are bought by the Chinese merchants for export to China (nine-tenths of the total trade). Dried shark fin is called "yu-chee" by the Chinese of San Francisco. It is soaked in water for two or three days, then cooked in soups or broths.

In China there is a more or less elaborate system of grading shark fins. They are classed either as white or black although none of the fins is entirely black or perfectly white. They are divided into a number of groups with different values, depending on color, size, and variety. The most important commercial grades of fins are the following: white spotted fin (boon leong sit), divided into large and small white fins; large white fins (chu sit); small white fins (peh sit and khiam sit); large black fins (tua sit); small black fins (oh sit and seow oh sit) and small black-tipped fins (oh ku sit) (Seale 1914).

STOCKFISH

Stockfish or "torfisk," as it is known in Norway, is one of the most important fishery products of that country. Stockfish are cured entirely by air drying without the use of any salt. This product has been a staple article of trade in Europe for at least a thousand years. In the Middle Ages it was one of the few protein foods which could be preserved over a long period. Dry salt fish were not manufactured so extensively then because of the higher cost of salt. Also, conditions of handling in that period required a product with a lower moisture content than the average dry-salt fish.

Stockfish has a large market both in Europe and in Africa. It is also sold in the United States especially in centers with large populations of Scandinavian or Italian origin. All species of the cod family are used in the preparation of stockfish: cod (*Gadus callarias*), haddock (*Melanogrammus aeglefinus*), hake (*Merluccius* sp.), cusk (*Brosme brosme*), and in addition such fish as coal fish. Cod is the chief source of raw material, however, and is supposed to make the best grade product.

The fishing area is in the northern section of Norway, with Lofoten as an important center. Fishing is done with hand lines, trawl lines (long lines), and gill nets. The curing stations are usually within a short distance of the fishing grounds. The fish must be especially fresh if they are to make a good quality stockfish. The fish should also be bled as soon as possible after catching. Old or bloody fish will turn sour more easily and are more liable to become wormy, especially if the weather is warm and still.

The first step in the manufacture of stockfish is butchering. This is usually done on land at the curing station but it is done on board if the fishing boats are to remain at sea for more than one day. The process of butchering is as follows: The belly is split open from the pectoral fins to a little below the anal opening, leaving the isthmus in a solid piece. A special knife is used to eviscerate roe cod as the ordinary type damages the egg sacs. The head is then cut on the ventral side as far as the backbone, the cut following a line just in front of the pectoral girdle. A quick jerk is used to break the head loose from the body.

A second man removes the roe and liver, which are placed in barrels to be saved for later use. He also cleans the fish, removing all visceral material, blood, and other offal. The airbladder is allowed to remain since it is desired by the Italian trade. Stockfish lacking the airbladder is considered of inferior quality in the Italian market. During the summer months all but the very smallest fish are split in two except for a short section near the tail. About two-thirds of the backbone is also removed. Stockfish dressed in this manner is known as "rotskjar" or split fish. "Rundfisk" or round fish are fish that have been beheaded and gutted but have not been split.

After being gutted the fish are thrown into large tanks of sea water for washing. The washing is sometimes not too well done, but Norwegian authorities on fish curing advise that it should be done very carefully, taking care to remove all traces of blood, liver and kidney. If these are allowed to remain a really good cure cannot be obtained as the fish are apt to turn sour and soft.

After washing, the fish are dipped from the tanks to a platform for tying, which is usually done by children. The tails of two fish of about the same size are put through a loop of strong twine about three inches in diameter. The fish are turned around two or three times so the loop of the cord twists enough to bind the fish. When the fish have been tied in pairs by the tails they are taken to the drying racks in wheelbarrows or special carrying boxes and slung so that the two fish of a pair hang on either side of the drying pole. Two fish hanging in the same loop of twine should not touch more than is necessary. They should not be hung too closely together for good air circulation.

The location and arrangement of the racks is of the utmost importance. They are usually rectangular in shape, and of all sizes, from small to large. The structure resembles a gridiron, about 9 feet above the ground. Poles stretch from one side to the other, about 2 or 3 feet apart (fig. 3). The racks should be built over dry and airy ground, preferably over bare stone. Consideration of the prevailing winds is important, as the racks should be so set that the wind blows between the rows of fish. A good drying climate is the chief essential in curing stockfish. The air should be dry and there should be a steady breeze. The temperature should not be warm, yet not so cold as to freeze the fish.

At most large drying stations one man is kept busy attending to the racks of drying fish. Each pair of fish is turned at intervals of a few hours, sides that were in being turned to the outside. If two fish are allowed to touch for more than a short period, soft spots will form which may become rotten if the fish are not turned. Rotskjar (split fish) are hung individually by the tail in such a way that one-half of the fish hangs on each side of the pole. A two-pronged stick is generally used for hanging up the fish and taking them down.

Thorough cleanliness in and around the drying racks is essential, to prevent damage from blowflies. If any birds, such as crows or seagulls, are around, freshly hung fish should be protected by an old piece of fish netting or some other device. The fish are not considered thoroughly dried if an impression can be made when the thick flesh along the backbone is pressed between thumb and forefinger.

When the stockfish take on a golden color and are so thin and dried along the backbone that the individual vertebrae can be counted, they are ready for removal to storage. Stockfish should be taken from the racks only on a dry day. No moisture should appear on the surface of the fish. If there are any bird droppings, oil, or other dirt on the fish these should be washed off, and the fish allowed to dry afterward. The dried fish are stacked loosely to permit free circulation of air. The doors to the storage rooms are opened in dry weather, otherwise they are closed to keep out all dampness. Most of the fish are shipped in bulk by coastwise freighter to Bergen where they are held in the exporters' warehouse until required for sale.

When the stockfish are to be shipped they are sorted out into piles according to grade. Grades are largely determined by the market, the buyers often sending speci-

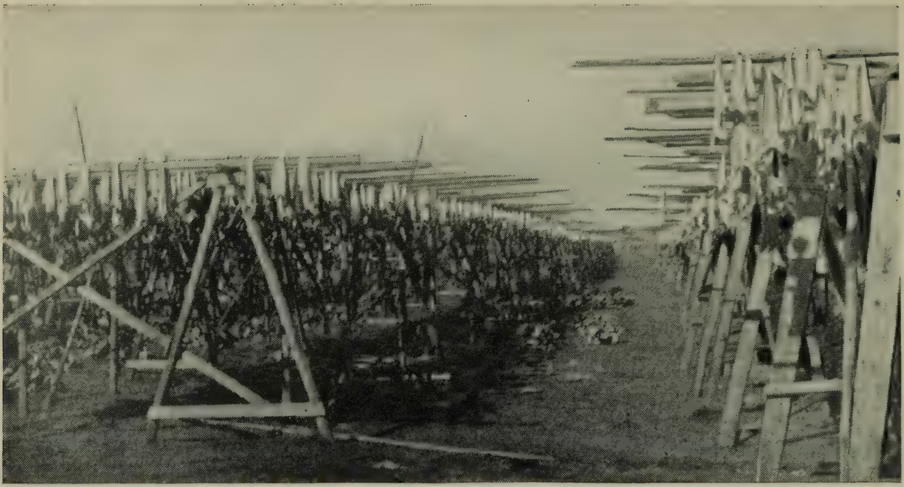

Figure 3.—Drying stockfish, Norway.

fications. In general the product is graded first as to the species of fish or manner of splitting as follows: (1) rundfisk (round fish)—cod; (2) titling—small round cod; (3) rotskjar (splitfish) — cod; (4) hyse—haddock; (5) sei—coalfish; (6) brosme—cusk; and (7) lang—ling. Second, it is graded according to size. The accepted size grades are:

Rundfisk (cod):	*Market*
Fish per 100 kilo (220 lb.):	
100 to 120	Italian.
130 to 150	Dutch.
180 to 225	Fine Dutch.
Titling (small, round cod):	
250 to 350	Dutch titling.
400 to 600	Bremer titling.

Third, the product is graded according to quality. There are two quality grades: (1) Prima or first, and (2) secunda or second. Fish are graded as second class for quality that were old when cured, bloody, not properly split, the air bladder or sound removed, frozen in drying, discolored, wormy, or moldy.

The greater part of the Norwegian stockfish is packed for shipment at the exporters' warehouses in Bergen. The ordinary package is 50 kilograms (110 lbs.) but occasionally may be 100 kilograms (220 lbs.). Fifty kilograms of the grade desired are weighed out and packed carefully in a hydraulic press. The stockfish are then pressed to about one-third of the volume of the loosely stacked fish. The bale is bound securely with three wires. It is then taken into another room where a cover of sacking is sewn on. The package is stenciled with the grade, packer's name, and any other necessary shipping marks (Jarvis 1932b).

The principal markets for stockfish are Italy, Spain, the Netherlands, Sweden, and Denmark. The cheaper grades are sold to the Negro trade in Africa. Recently this market has increased in importance and is demanding better grades of fish.

Before cooking, the stockfish

should be softened, or disintegrated by beating with a wooden club, and all bones removed. The fish are then soaked for several hours, washed, and drained. In Italy, thin fish are preferred to thick fish and the disintegrated flesh is placed in cold water over a fire, being removed just before the water reaches the boiling point, since boiling toughens the texture. Steaming is a better method of cooking, making the flesh white and soft. In the Scandinavian countries stockfish is made into "lutefisk."

The Russians cure a certain amount of stockfish in the coastal area bordering on northern Scandinavia. The method of preparation is somewhat different from the Norwegian cure. The fish are split through the back and left solid in the belly. A cut about an inch long is made through the uppermost part of the fish and through this the fish is tied up on the drying rack. Stockfish are also prepared in a manner similar to the Norwegian split fish except that the backbone is usually not taken out.

Alaska

Some stockfish is prepared in Alaska. There are two small shore stations for making stockfish in the Shumagin Islands. A few small temporary operations are carried out in other parts but the climate of the greater part of the Alaska coast is not particularly suitable. Most of the fish are prepared during the winter months when the climate is more favorable. About 12,000 pounds of stockfish were cured in Alaska annually just before World War II. A network of wires is used instead of poles for racks.

Stockfish may be prepared in artificial driers. This has been demonstrated in Halifax with the drier developed at the Atlantic Experimental Station of the Fisheries Research Board of Canada.

STURGEON PRODUCTS

Veziga

The spinal cords of sturgeon are dried for a food delicacy in Russia, Rumania, Iran, and other Asiatic countries where sturgeon are taken in large quantities and, also, to a small extent, in the United States on the Columbia River, where this product is prepared by Chinese. The spinal cord is removed from the backbone after the head has been removed and the tail cut off. Enough of the spinal cord is pulled out at the tail end with a baling hook to give a good grip for the hands. The spinal cord is pulled out hand over hand until a section about four or five feet long has been removed. This material is cylindrical, whitish in color, and marked or constricted at intervals like a string of link sausages.

It is first washed thoroughly to remove the blood and slime. The cord is hollow and filled with a jelly-like substance which is pressed out by squeezing the cord between the fingers. The larger cords are split lengthwise instead, so that this material may be cut or scraped out and discarded. After cleaning, the spinal cord is washed again in fresh water until it is quite clear in color.

It is then hung in a current of air until thoroughly dry.

The whole dried cords are tied up in bundles for marketing or they may be cut in four- or five-inch lengths which are tied together in small bundles. This product goes by the Russian name "veziga," and used to sell for one dollar or more per pound on the Columbia River. The last quoted New York price was five dollars per pound. It takes 25 average-size sturgeon to make one pound of veziga. The best market is with the Chinese, who use it in fish soups, pies, chowders, and similar dishes.

Balyk

Some sturgeon meat is dried in Russia, where it is known as "balyk." This should not be confused with "beleke," an Alaskan dried and smoked salmon, believed to have been introduced by the Russians. The back flesh only is used in making balyk, the other portions being salted or preserved in some other way. In Russia, the backs of the common sturgeon (*Acipenser guldenstadtii*) and of the "sevriouga" (*Acipenser stellatus*) are cured in a single piece, while those of the large sturgeon (*Huso huso*) are cut either lengthwise only, or else both lengthwise and crosswise. The pieces are placed in a tub so as not to touch each other or the sides of the tub. They are then covered with a thick layer of salt and left from 9 to 12 days. The salt is mixed with saltpeter in the proportion of two pounds of saltpeter to 50 poods (1,800 lb.) of balyk in order to give a reddish color. Allspice, cloves, and bay leaves are frequently added to the brine. The pieces may be left in salt as long as 15 days if they are large or the weather is hot. When the salting is finished, the pieces of sturgeon are soaked in fresh water for about 24 hours to remove excess salt. Then they are dried, first in the sun and then in the shade, on roofed scaffoldings, which are built for this purpose.

The process of drying requires from four to six weeks and is considered finished when the growth of a slight mold covers the balyk. The absence of mold indicates that the balyk has been salted too much. Good balyk must be soft and tender; must have a reddish or orange-brown color; and must also have an odor something like that of the cucumber. It must also be transparent, show no traces of putrefaction, have no bitter taste, and not be too salty. Balyk which meets all of these requirements is considered a strictly fancy grade and sells at a high price. Only a few fish curers are able to make such an article, according to information from Russia.

MISCELLANEOUS FISH

The Chinese who operate the shrimp drying platforms in Louisiana also dry a considerable quantity of fish each summer. Chinese in the San Francisco Bay area also cure each year some miscellaneous fish by air drying. All varieties of salt-water fish are dried, except the small bony ones and the excessively fat. The varieties most commonly used in Louisiana are croakers, red drum, sea trout (squeteague or weakfish), sheepshead, and whiting.

The method used in Louisiana is primitive. Few of the fish are dressed before drying, the heads, scales, fins and viscera remaining, except that the large red fish or channel bass are eviscerated and have the heads and fins removed. In a few instances the fish are given a short brining. The fish are spread out on small slatwork frames, about 8 feet long by 4 feet wide. These frames are set on some type of support and the fish are left to dry in the sun. They are turned every few hours by placing a second frame on the one holding the fish, turning both together and then removing the first frame. Drying requires from one to three weeks, according to the size of the fish and weather conditions. The product is sold entirely to Chinese markets in the United States.

The fish dried in the San Francisco Bay area are usually made from fresh fish left unsold at the end of the day. They are spread on the roof tops, turned at intervals, and left until dried. Production is now only a small fraction of the former level. With improvement in refrigeration facilities and change in food habits, this product may soon disappear from the market.

ABALONES AND OTHER SHELLFISH

The abalone (*Haliotis* sp.) is prepared on the Pacific coast, where it is a dried product of some importance. At one time, abalones were dried as far north as southeastern Alaska, by the Indians. Now abalones are cured only in southern California and Mexico, by Chinese and other Orientals. The dried product is considered a delicacy by Orientals. Considerable quantities are shipped at times to China, Hawaii, and the Philippines.

Abalones are found at depths from the low water mark up to about 12 fathoms. They are gathered by men in diving suits who pry them loose from the rocks with an implement resembling a tire iron or long-handled chisel. If the iron is slipped quickly under an abalone it is easily detached; but if there is any hesitation the mollusk contracts the muscular foot, and it can only be pried away with difficulty. The diver throws his catch into a net bag or a basket lowered from the boat; he signals when the receptacle is full and the abalones are hoisted aboard. A diver works about three hours at a time.

When the abalones are brought ashore the first step in preparation is to remove them from the shells. The meats are kept for several days in a salt brine testing about 50° salinometer. The purpose of brining is to remove the mantle fringe and preserve the meat during the drying period. When sufficiently brined the abalones are washed, cooked for about 30 minutes in water just below the boiling point, and transferred to shallow trays, where they are spread out to dry in the sun. The meats are turned at intervals during the first part of the drying process. After four or five days the abalones are given another cooking, this time for 60 minutes.

After the second cooking the abalones are dried for a day over a low charcoal fire. They are then rinsed in boiling water and spread out again for the final drying, which requires about six weeks. The dried abalones are rinsed in warm water, wiped, and packed for shipment. The meats lose about 90 percent of the original weight in the curing process. The dried product resembles a piece of hard, tough gum rubber, yet it can be sliced or shaved off in shreds with a sharp knife. The Chinese grind dried abalone to a powder and use it as an ingredient in soups and stews. It can also be soaked and stewed.

A number of other shellfish are dried, mostly in the Orient, with occasional manufacture in the Americas. Considerable quantities of a clam much like our Pacific razor clam are dried in the Orient. These clams are shucked, boiled in salt water about 10 minutes, then spread on bamboo trays to air dry. From two to three weeks are required for drying. The Indians on both Atlantic and Pacific coasts formerly dried quantities of hard clams as a regular part of their winter food supply. Some clams are still dried occasionally by Alaska natives. The clams are shucked, strung on cords, partially dried in the sun, then hung in the rafters of their huts to finish curing over the smoke of the fire. Some oysters are dried occasionally by Chinese shrimp driers in Louisiana. The oysters are handled much like shrimp. Production is almost entirely for use locally though small lots may be shipped to other Chinese settlements in the United States. Mussels are also dried by immigrant fishermen. A New York firm placed a dried clam broth tablet and a dehydrated oyster powder on the market about 15 years ago. The principal difficulty with the oyster powder was the high price at which it had to be sold.

DRIED OCTOPUS

Dried octopus is called "pulpo" by the Italians and Greeks. It is also popular with the Oriental trade in this country and a great deal is prepared throughout the Orient. Small quantities have been dried from time to time in the Pacific Northwest and it is cured more or less regularly in California by Orientals for local use. Most of the dried octopus consumed in the United States is imported from the Mediterranean area and the Orient.

Levantine Cure

Octopus for the Levantine trade in the United States is prepared by gutting or eviscerating the octopus and washing thoroughly in sea water. The octopus are spread out to dry in the sun on wooden trays or drying frames, elevated a few feet above the ground. As a rule no salt is used unless the weather is unfavorable for drying, or the octopus not strictly fresh. All sizes are used from the very small specimens dried in a single piece to giants, which may be cut into sections. The drying period may vary from 10 days to 2 weeks, depending on the weather and the size of the octopus.

Oriental Cure

The Oriental cure is much the same as described above although another variant is sometimes used. After cleaning, the octopus are simmered for about three-quarters of an hour in water just below the boiling point. They are then spread out on drying frames in the sun. A low charcoal fire is sometimes used in drying.

SQUID

Squid are dried extensively in the Orient, especially by the Chinese and Japanese. They are also cured in the Mediterranean where the product is known as "kalamar." While squid are found on both coasts of the North American continent they are dried for market only in California, at present, although they have been dried in Newfoundland. The species utilized is the common squid (*Loligo opalescens*) of the Pacific coast, which has an elongated, pointed body, with triangular fins near the posterior end. This squid ranges from Puget Sound to San Diego. Although a few are caught throughout the year, the period from about April 1 to June 30 is considered the regular squid-fishing season.

The fishing area is almost entirely within the limits of Monterey Bay, with the waters off Moss Landing and Watsonville as important catching areas. Sardine nets such as half-ring nets are probably used most widely, with some lampara nets and a few purse seines. Like sardines, the schools of squid can usually be located only at night in the "dark of the moon" by the phosphorescence of the water resulting from their movements. The only distinction in locating squid rather than sardines is that the former species causes a "fluttery" or "wriggly" phosphorescence in the water, while sardines produce more or less straight lines.

The squid are landed at Monterey within two or three hours after catching, so that no special care in handling is required. They are unloaded at the fresh fish market dock, into wooden fish boxes or piled loose in a deep truck body, then transported to the drying place.

The method used in drying squid is not standardized. It may vary with the curer and according to the quality of the product to be prepared. The best quality squid are first sorted for size. They must be fairly large, from 10 to 18 inches in length. The squid are first washed and split. The quill and sepia bag are removed, and the inside of the body is scraped thoroughly. They are spread out flat to dry, usually on a stretch of hard, bare ground. The squid must be turned at frequent intervals the first few days. As a rule no salt is used in curing. The squid are collected every evening and taken to a warehouse to be protected from night fog and dew. In good weather approximately 10 days are required for drying. When the squid are thoroughly dried and hard, they are packed in barrels to a net weight of about 135 pounds; sometimes in boxes, or matting-covered bales, and shipped to market, usually to San Francisco. It is reported that when properly dried, squid packed in this way will remain in good condition for a year or more.

Second-quality squid are not selected so carefully, either as to size or freshness. They are split, washed, cleaned and scraped, salted lightly or brined for several hours, then spread out to dry. They are turned by hand, as are the first quality squid, and require about the same degree of drying. The sale price is somewhat lower.

There is a third grade of dried squid which is distinctly inferior to either of the first two. It is made from the smallest squid, or those taken incidentally in other fishing operations. These squid are not given any preparation, such as cleaning or splitting. No salt is used in curing. The squid are spread on the drying grounds in layers up to 2 inches in thickness. They are turned with wooden or bamboo rakes, as is done in drying shrimp, at appproximately 30-minute intervals for the first two days, and at less frequent intervals for the balance of the cure. When dry the squid are shoveled into sacks. The product is then ready for shipment. This quality of dried squid is shipped almost entirely to China where it is sold to the lowest-price market.

Dried squid is called "yu chee" by the Chinese, who consider it a delicacy when properly cured and cooked. Some dried squid is also imported from China. This is a first-quality squid, large, well selected and hard dried, and sells for about three times the retail price of the best domestic product.

SHRIMP

Sun-dried shrimp probably originated in Asia. The method was introduced into the United States by Chinese, who began a shrimp-drying industry in California some time in the 1860's. Some shrimp are still dried in California. but due to overfishing and restrictions on the use of the bag net formerly used by Californian Chinese, production declined to 139,000 pounds in 1941. The drying of shrimp was begun in the Gulf of Mexico area in 1873 by a Chinese named Chin Kee. Production of sun-dried shrimp in the Gulf area averages 2,000,000 pounds annually. The development of canning and other methods of preparation has also caused a decline in Louisiana shrimp drying.

Chinese-Americans still handle the marketing of sun-dried Louisiana shrimp, but the shrimp are now cured mostly by "cajun" shrimp fishermen in the Barataria Bay region. Chinese - American fishermen prepare the dried shrimp in California, largely in the San Francisco Bay and Monterey areas.

A shrimp-drying camp consists of a warehouse, storehouse, living quarters, some sort of wharf, platform on which the shrimp are dried, and boilers for cooking. The drying platforms are built near the edge of the water and stand on posts 8 to 10 feet above the level of the ground. They are usually made of cypress. The platforms range in area from 25,000 to 50,000 square feet. One of the largest shrimp drying platforms in Louisiana is 230 feet long by 130 feet wide and has a capacity of about 1,000 baskets of shrimp, or approximately 100,000 pounds. The floor of the platform is not level but has an undulating surface with an ocean-wave effect. These "waves" are about 2 feet in height, with a distance of about 30 feet from crest to crest.

The shrimp are brought directly to the drying place by fishing boats. The driers utilize the small shrimp, which are not in great demand for canning, freezing or for sale in the fresh market. The first step is to wash the shrimp and clean them of debris such as seaweed. They are then dumped in large iron kettles holding about 900 pounds. From 10 to 20 one-quart measures of salt are added to each batch, depending on the weather. More salt is required in damp weather than in dry. The shrimp are put in the kettle when the water is actually boiling and the cooking time begins only when the brine again comes to a boil. The cooking time varies from 15 to 45 minutes, depending on the size and amount of shrimp and the weather. The method of determining when the shrimp are sufficiently cooked is to hold one up to the light and observe the shrinkage of meat within the shell. If there is a clear space between the meat and shell the shrimp are cooked.

When sufficiently cooked the shrimp are dipped from the vats into wheelbarrows, drained for about 15 minutes, then taken to the drying platforms where they are spread. The cooking water is changed only about every fifth or sixth lot, but salt is added each time. With long wooden rakes the shrimp are spread out to dry in layers with a maximum thickness of three inches. They are never spread to the maximum depth unless the size of the catch makes it necessary. The shrimp are raked over several times each day to promote drying and prevent spoilage. The frequency with which the shrimp are turned depends on the thickness of the layer, a layer three inches thick requiring attention every 20 minutes.

Each night the shrimp are shoveled and scraped into long low heaps on the crests of the ridges of the drying platform. They are then covered with tarpaulins placed over A-shaped trusses set across the ridges to protect them from rain and dew. The covering must be fixed so as to furnish an opening at each end of the heap to provide for adequate ventilation. If this is not done, the shrimp heat and spoil. When the shrimp are fairly well dried, the tarpaulins may be spread directly on the shrimp, but not in the earlier stages of drying, when ventilation is absolutely necessary.

If the weather is favorable the drying process will require from 24 to 48 hours, depending on the thickness of the layer, the degree of atmospheric humidity and the average size of the shrimp. If rain seems imminent the shrimp are shoveled into heaps on the top of the ridges and are covered by tents formed from the trusses and canvas. The value of the wave type of construction is now apparent, for even in the hardest rain the shrimp cannot get wet, the water draining away down the hollows. When the sun comes out, the shrimp are again spread out and the drying process continued. If a long period of wet and cloudy weather sets in while the drying platforms are full of shrimp that are still quite green, the whole lot is lost by spoilage. If the drying process is fairly well advanced at the beginning of the rainy period, the shrimp can be gathered and held in the storehouse for a long period. When clear weather returns they can be re-spread on the drying platform to complete the drying.

When the shrimp are thoroughly dried the shells are removed mechanically. Formerly, they were shoveled into large round piles on the platform. The workmen bound sacks on their feet and then trampled the shrimp, going round and round the pile in what may be best described as a slow trot. The process is called "dancing" the shrimp. The trampling separated heads, shell, legs, and other waste parts from the meats. The waste is known as "bran." This method is now used only by a few of the smaller and less progressive packers.

When the shrimp have been well "danced" or shelled, the meats are separated from among the shells by sifting on a coarse wire screen with about ¼-inch mesh. This does not remove all particles of shell from the shrimp meats. Some firms follow the practice of placing the meats in sacks, which are beaten with boards, after which the shrimp are sifted again. Other driers do not think that the slightly higher price is sufficient to pay for this trouble and pack the meats for shipping without additional cleaning.

Dried shrimp meats are packed in large sugar barrels, to a net weight of about 230 pounds. Some are sold in the United States; in fact, use here is increasing in recent years. The prinicpal market, however, is among Latin and Asiatic peoples. Much dried shrimp is exported to Central and South America, Cuba, China, Puerto Rico, and the Hawaiian Islands. It is very good when used in such southern dishes as jambalayas and curries.

A basket of "green" shrimp, weighing about 105 pounds, should yield about 12 to 14 pounds of dried shrimp meats. The quantity of bran obtained is usually equal to that of the meat.

The "bran" is usually sold locally. It is put up in sacks, about 30 to the ton, and sold either as fertilizer or meal. The shortage of protein materials for stock feeds has led to a study of the use of shrimp bran in animal feeding. Investigators have shown that it has high nutritive value, being an excellent source of both protein and minerals. It is fed to livestock and poultry.

Shrimp drying in California is carried out somewhat differently. It is conducted on a smaller scale, and is probably closer to the original Asiatic method. The shrimp are first boiled in brine. Apparently, the strength of brine varies with the individual curer. When the shrimp are cooked they are dipped into baskets and taken to the drying area. This is a hard-packed area of ground, free from pebbles, and vegetation. The shrimp are spread out in a thin layer and turned occasionally with a long-handled bamboo rake. At night they are brought inside. Drying should be completed in four or five days. The shrimp are then piled and trampled on or beaten by wooden clubs to release the meats from the shells. Meats and shells are separated by a crude fanning mill on the same principle as the old-fashioned mills for winnowing grain.

TREPANG

The trepang are holothuroidean echinoderms known in English as sea cucumbers or sea slugs. The dried flesh of the trepang is a very popular food in Oriental countries, where millions of pounds are consumed every year. It is cured extensively in the South Pacific islands, the Philippines and Japan. The sea cucumber is found in large quantities off the coast of Florida, in the Caribbean and the Gulf of Mexico, on the Atlantic coast of the United States. They are found from California to Alaska on the Pacific coast and are known to be abundant in the Puget Sound area. According to Stevenson (1899) trepang were cured in Florida for a short time. No effort has been made to cure trepang in the United States for many years, though sea cucumbers were canned in the Puget Sound area for several years preceding World War II. The product resembles minced clams.

Seale (1917) reports that there are about 16 principal varieties and 47 commercial grades of trepang in the Philippines, which range from white to black in color. Some are smooth, others are covered with prickles. Live sea cucumbers are from 12.5 to 45 centimeters or more in length, but when dry they are seldom more than 20 centimeters in length and from 2.5 to 8 centimeters in diameter. When properly cured, they look like a bologna sausage and should be dry enough to "rattle like walnuts in a bag." Each species of commercial trepang is divided into three grades; namely, large (toa), medium (tiong), and small (liow), with corresponding values.

The sea cucumbers are taken both by spearing and by diving. To spear sea cucumbers the fisherman usually walks along the reefs at low tide. When he sees a sea cucumber it is transfixed on the point of a single-tined spear and transferred to a bag carried at his waist. Sea cucumbers making the best quality of trepang are taken in water from 10 to 30 feet deep and are usually taken by diving. Naked-diving has been the rule but more recently divers have been using helmets. The naked diver drops to the bottom in a favorable spot, fills a basket or bag with the slugs and comes to the top. The diver wearing a helmet works continuously up to three hours, piling his catch on a container lowered on a rope, jerking on the rope to signal the fishing boat above that the basket is full.

Air Drying

There are several variations in the method of drying trepang, of which the more important are air drying alone, a combination of air and fire drying and drying entirely over a fire. In curing trepang by the first method, the sea cucumbers are taken ashore as soon as possible and dumped into a pot of sea water. They are split down the side, scraped clean and rinsed and boiled from 10 to 30 minutes, depending on size and variety. The cooked slugs are taken out and spread on racks of reed or bamboo to dry in the sun. The trepang must be turned at frequent intervals during the first part of the cure. Drying takes approximately 20 days in good, clear weather.

Combination Air and Fire Drying

The second method is used generally in the Philippines and is described by Seale as follows:

> After the trepang are gathered, they are taken to the curing station and cared for promptly; otherwise they become a blubbery, unsavory mass within a few hours. They are first placed in a pot or cauldron of water (an oil tin would answer the purpose) and boiled for twenty minutes (some require less time). When taken out of the boiling water, they should be hard and elastic and should dry quickly, like a hard-boiled egg. They are slit open with a sharp-pointed knife, and the entrails are removed. They are next placed in the sun and left until almost dry and then transferred to a smokehouse and smoked for about twenty-four hours. The smoked trepang are spread on a mat in the sun until almost dry and then transferred to a smokehouse and smoked for about twenty-four hours. The smoked trepang are spread on a mat in the sun until perfectly dry. Finally, they are packed in bags. Trepang are prone to collect moisture, and if kept for three or four weeks they must be again spread out, and dried in the sun to prevent molding.

Fire Drying

In the East Indies, especially on the Malay Peninsula, where storms come up frequently, trepang are dried by fire only. This process is sometimes called smoking, but there is not sufficient smoke to cure the trepang, and preservation depends entirely on the drying action of the fire. The first step is to erect, what is for this area, a large curing house of substantial construction. It has narrow entrances. An average-sized house is 90 feet long, 30 feet wide, and 10 feet high. It is covered with a thick thatch or coconut leaf matting, well put on so as to prevent rain from penetrating. Drying platforms are then built along one side of the shed. There are two of these, 8 feet wide, the lowest about 4 feet above the ground, the second about 3 feet above the first. The platforms are generally made with a framework of coconut trees, and a covering of split bamboo or reeds. Under the platforms a trench about 6 feet wide and 2 feet deep is dug, running the entire length of the house. This is used to hold the low fires for drying trepang.

The curing process is as follows: The trepang are first gutted, then boiled from 15 to 20 minutes in large iron kettles filled with sea water. When sufficiently cooked they are washed well with fresh water and carried in small wicker baskets to the curing house, where they are spread out to dry on the lower platform in a layer four or five inches thick. The trench is filled with firewood and lighted, and the drying process begins. From this time the fire must be kept going day and night.

On the first day of curing the slugs must be turned rather often. The next day the fires are put out and the drying trepang are moved to the upper platform. If some are not drying properly, they are transfixed with splints of wood. The lower platform is then filled with freshly boiled slugs, the fires are relighted and the drying goes on. At the end of second day the trepang on the upper shelf are inspected, then shifted to one end to make room for another batch from the lower platform. The drying is continued for two more days. The first day's batch should then be cured. It is taken down, examined carefully and packed in bags. Any slugs not completely cured are given additional drying. The fires must always be extinguished when loading or unloading the drying platforms. Unless packed in airtight containers the trepang must be re-dried in the air at intervals of about 12 weeks as it soon becomes damp again.

The method of fire drying is used most extensively for two reasons: it is much quicker as 4 days are required for curing against 20 days for air drying; and also larger quantities can be handled more readily. However, sun dried trepang is considered of better quality and brings a higher price.

Trepang preparation is not easy. Gutting must be done carefully, in a large quantity of water, or the trepang putrefies. This also occurs unless curing begins within a very few hours after catching. The trepang blisters and becomes porous if too much heat is used in drying and if there is not enough heat, it putrefies.

SEAWEED

Dried seaweeds are used for human food in many parts of the world, though they are used most often in the Orient. Over a dozen varieties of dried edible seaweeds are sold to the Japanese trade, some bringing three dollars a pound. According to Tressler, "the edible seaweed industries are among the most valuable of the aquatic industries of the Japanese."

The two seaweeds used most widely for edible purposes in the United States and Europe are Irish moss or "carrageen" (*Chondrus crispus*) and dulse (*Rhodymenia palmata*). Irish moss is found along the Atlantic coast of North America from North Carolina to Nova Scotia. This is also the general range of the dulse. The Irish moss is gathered commercially at points in Massachusetts, New Hampshire, and New York, and the Province of New Brunswick in Canada.

Irish Moss

Irish moss is gathered from the rocks by means of rakes handled from boats. Some is gathered by hand, especially from the shallow pools near the high water mark. The season for taking sea moss runs from late spring to early fall. If the rocks have not been scraped too closely in the first part of the season, it is said to be possible to get a second crop in some of the warm sheltered coves, where growth is more rapid than in exposed locations.

Good weather with sunshine is essential to curing Irish moss. When brought ashore the weed is washed in sea water, then spread out on the beach to dry and bleach. If the weather is good the Irish moss is gathered after 24 hours and given a second thorough washing in sea water and again spread out to dry. The moss should be completely cleaned and bleached after 3 washings, or about 72 hours, though sometimes it is washed as many as 7 times. After the final washing the weed is left in the sun until it is completely dried. This usually requires about two weeks of good weather with sunshine. The Irish moss gradually loses its color in this drying period, finally becoming almost white or light straw color.

Drying is an operation requiring great care, and rainy weather can easily spoil the Irish moss. The weed must be raked up and covered at the first sign of rain. Irish moss is used chiefly for making blancmange, other puddings, and jellies. It is also used as a stabilizing agent in foods and beverages, as for example salad dressing and chocolate milk.

Dulse

Dulse is particularly abundant from New England to Nova Scotia. It is found on rocks near the shore. The process of preservation is very simple. After washing in sea water to remove sand or other debris, the dulse is spread on rocks or shed roofs to dry in the sun. Much of the dulse consumed in New England is imported from Nova Scotia, in light wooden boxes holding about five pounds, or in sugar barrels shipped loose. For retail sale the dried weed is packed in small cartons holding about four ounces, like those used for shredded codfish. It is eaten as a relish and is used in stews as a thickening and flavoring agent. The Scotch and Irish sometimes chew the dried weed instead of tobacco. It is valued for its high iodine content and is used in the prevention of goiter.

DEHYDRATION OF FISH

DEFINITION AND PRINCIPLES OF DEHYDRATION

There is some confusion in applying the word "dehydration" to fish-curing methods. The term is sometimes used loosely. The following definitions have been suggested by D. L. Cooper after a discussion on the subject with the writer. "Dehydration is the drying of fish protein, with or without the addition of salt, without respect to form. Drying is the dehydration of fish, with or without the addition of salt, in which the structure and form are retained."

According to Tressler (1923) dehydration preserves fish by destroying enzymes and removing the moisture necessary for bacterial and mold growth. Fat fish cannot be dehydrated by the ordinary dehydration processes, nor is it possible to store dehydrated fat fish in the usual way; as fish oils, or fats, are drying oils which rapidly absorb oxgyen from the air and harden just as paints harden on exposure to air. Fatty fish must be dehydrated quickly in a vacuum, and must be stored in vacuo or in an atmosphere of an inert gas.

PREVIOUS WORK

Experiments in the dehydration of fish have been conducted over a period of 70 years. Most of the early experimental work was haphazard, and none of the methods developed was successful. Stevenson (1899) describes some of the early efforts, which were tried at the same time on fruits and vegetables.

The dehydration of fish has been studied in Germany and Norway for many years, and it is reported that scientific methods were applied successfully as early as 1913. There are a number of references made to the subject in German technical journals. Tressler (1923) describes a process for the dehydration of fish put into commercial operation in Cuxhaven, Germany, about this time. Though references from German sources claim the development of successful methods for the dehydration of fish, so far as can be determined there was little or no dehydrated fish used during the war period of 1939–45.

STUDIES IN WORLD WAR I

At the time of the first World War a comprehensive study was made in the United States by Scott and Wolff (1936), under the direction of the United States Bureau of Fisheries, and the data were summarized by Tressler (1923). This investigation is the first scientific study reported in English on the dehydration of fish. These workers found that raw fish did not dehydrate well; that fish must be precooked to obtain a dehydrated product of satisfactory quality. They determined also that the cooked fish must be flaked and ground before dehydration. It was also concluded that moisture content should be reduced to one percent or less to avoid changes in protein after dehydration. Dehydration *in vacuo* gave the best results, but this method was considered too expensive. Oxidation in storage was a serious problem. Light was also found to cause deterioration in the stored product. The best results were obtained with non-fatty fish packed in hermetically sealed containers and stored in a cool place.

The method of Scott and Wolff in Marine Products of Commerce required that the fish be cleaned in the customary manner. Heads, viscera and fins are removed and the fish are scaled. They may be skinned either before or after precooking; as a rule it is done more easily and quickly after cooking. The cleaned and washed fish are placed in shallow pans with perforated bottoms and cooked in a steam chest under pressure. The process used was 20 minutes at 12 pounds pressure (244° F.). The flesh is picked from the bones of the cooked fish as soon as possible. The flaked fish are run through a grinder, using a plate having perforations three-sixteenths of an inch in diameter.

The ground fish are spread on shallow drying trays in a thin layer. The loaded trays are placed in driers and the moisture is removed by currents of warm air. The temperature in the drier is about 145° F. at the start. As the process continues, the temperature is gradually reduced, because too high temperature gives a noticeably discolored product. The temperature of the fish must not reach that of the air in the drier. The drying is discontinued when the moisture content is reduced to five percent. This requires about two hours in a good warm-air drier. The dried product is ground coarsely and packed in air-tight containers.

Interest in the dehydration of fish was not great in the period following World War I. Some work was done in Norway on the production of a "fish flour" but the product was not accepted. A study on fish dehydration was conducted at the College of Fisheries, University of Washington, to test Scott's method and to determine what North Pacific coast species might be utilized. It was found that lingcod, *Ophiodon elongatus*), Pacific cod (*Gadus macrocephalus*), rockfish (*Sebastodes* sp.), Pacific halibut (*Hippoglossus stenolepis*), octopus (*Octopus punctatus*) and squid (*Loligo opalescens*) were suitable for dehydration.

A private firm in the United States produced two dehydrated shellfish products, an oyster tablet and a clam broth tablet which were put on the market during the 1930's. These products were of excellent quality but did not obtain a very wide distribution commercially.

STUDIES IN WORLD WAR II

The outbreak of the war created many problems in the transportation, preservation, and storage of foods. As a result there was renewed interest in dehydration. Much progress was made in the dehydration of fruits and vegetables. Products of high quality were developed and placed in large scale production. Some of these are having a reasonably good reception as commercial products. There was also interest in the possibilities of other dehydrated products, including meat and fish.

U. S. FISH AND WILDLIFE SERVICE

In 1942, when shipping space was extremely scarce and it was also feared that tin supplies might soon be exhausted, military and other government purchasing agencies indicated much interest in the possibilities of a dehydrated fish of good quality. As the problem fell within its sphere, the U. S. Fish and Wildlife Service included studies on dehydration in its war problems research program at its technological laboratories in College Park, Md., and Seattle, Wash. The work in the Seattle laboratory was principally engineering studies on the development of a satisfactory product and method of manufacture, with investigations on the effect of various processing methods, storage conditions and types of containers on the storage life of the product. At the College Park laboratory, attention was given largely to the suitability of different species for dehydration, the determination of the nutritive value of these species when dehydrated, and the possibilities of several new and untried types of apparatus in the dehydration of fish.

A horizontal tunnel drier in which temperature and relative humidity were automatically controlled and air velocity could be varied between zero and 900 feet per minute was used in the engineering studies. The drying section was 18 feet long, with cross sectional dimensions of 18 by 23 inches. It was provided with four racks, each holding seven trays with an area of 2½ square feet.

The investigators found that fish could be dehydrated successfully over a rather wide range of temperature conditions. Stansby (1944) reports that:

> * * * drying temperatures as high as 205° can be used in the initial drying stage without harmful effect. As the product becomes drier, it is necessary to use a lower temperature in order to prevent scorching and in the later stages temperatures above 145° F. are inadvisable. Relative humidities between 10 and 40 percent have no appreciable effect on the quality of the product. Low humidities and high initial drying temperatures are, of course, helpful in increasing the rate of drying.

This is in contrast to the earlier results of Scott (Tressler 1923) and the results of recent studies by the British Food Investigation Board (Cutting 1944) which give a maximum temperature of 70° C. (158° F.).

The staff of the College Park laboratory of the Fish and Wildlife Service cooperated with a number of manufacturers of industrial dehydration equipment used for other purposes to determine the adaptability of certain new apparatus. Both the Megatherm process utilizing radio-frequency energy as a source of heat and one employing high vacuum desiccation of the frozen material were given a preliminary trial. Results obtained from both types were promising, but since at the time neither was sufficiently developed for commercial use in the dehydration of fish, no attempts were made to work out a commercial process. Compression of dehydrated fish into small blocks was also given some attention at the College Park laboratory. Dehydrated fish were stored at various temperatures from 40° to 100° F. to determine the effect of varying temperatures (Young and Lee 1943).

SPECIES SUITABLE

Species considered suitable for dehydration include Atlantic cod (*Gadus morhua*); angler fish (*Lophius piscatorius*); Atlantic croaker (*Micropogon undulatus*); groupers (*Epinephelus* sp.); striped mullet (*Mugil cephalus*); puffer (*Spheroides maculatus*); sea robins (*Priontus* sp.); gray sea trout (*Cynoscion regalis*); rajafish or ray (*Raja* sp.); whiting (*Merluccius bilinearis*); and sea mussel (*Mytilus edulis*) from the Atlantic coast; burbot (*Lota maculosa*) and carp (*Cyprinus carpio*) from inland waters; and Pacific cod (*Gadus macrocephalus*); rockfish (*Sebastodes* sp.); Pacific halibut (*Hippoglossus stenolepis*); Pacific herring (*Clupea pallasii*); pilchard (*Sardinops caerulea*); petrale sole (*Pleuronectes* sp.); chum salmon (*Oncorhynchus keta*); king salmon (*O. tschawytscha*); silver salmon (*O. kisutch*); Pacific mackerel (*Pneumatophorus diego*); and squid (*Loligo opalescens*) from the Pacific coast.

STORAGE CHANGES

Storage changes taking place in dehydrated lean fish include development of a tough texture, darkening of color, and a burnt flavor and odor. Stansby (1944) states that:

> These changes are identical with those encountered with dehydrated eggs where such changes are attributed to a chemical combination between the protein and certain sugars which occur in only small traces in eggs. With dehydrated eggs these changes are minimized by reducing the moisture content to less than one percent. It seems possible that a similar improvement might be obtained by dehydrating fish to a similarly low level.

He concludes that unless the keeping quality of dehydrated fish can be greatly improved there is apparently no possibility of a domestic market for the product.

Cost of Production

Both Stansby and Young have made some estimates of cost of production. Stansby arrives at a figure of $1.50 a pound of finished product for cost of the raw material exclusive of all processing and overhead charges where haddock is used when the price paid to fishermen was about 30 cents a pound. Young made a more detailed estimate, including all factors in the cost of production such as labor, fuel, and overhead. His raw material costs are lower but the total cost of production is estimated at $1.80 a pound so that the price to the wholesaler would be approximately $2 a pound. Both conclude that even if "trash" fish were used, the cost of manufacture would be so high that the average consumer would be unwilling to purchase dehydrated fish. It is concluded that at present the outlook for development of a commercial dehydrated fish industry on a permanent basis, either for domestic or foreign markets, is not promising.

BRITISH MINISTRY OF FOOD

The most extensive studies of recent times on the dehydration of fish are those of the British Ministry of Food, Department of Scientific and Industrial Research, at the Torry Research Station, Aberdeen, Scotland (Cutting and Reay 1944 and Cutting 1944). This agency is also the only one which has placed dehydrated fish in actual consumption on any scale, so far as is known at present.

In the course of the experimental

work at the Torry Research Station eight types of "lean" fish were used, including five species belonging to the family Gadidae, and three types of "fat" fish; Atlantic herring (*Clupea harengus*); mullet (*Mugil* sp.), and Atlantic salmon (*Salmo salar*). These workers also came to the same conclusions as Scott, namely that experiments in drying raw fish, either in fillets or ground, showed this procedure to be unsatifactory. This was also true of whole cooked fillets. Cooked whole fish were not acceptable. Gadoid fish and herring were dried both fresh and cooked, and smoke-cured before cooking. The smoke-cured herring are believed to make a more acceptable product than the fresh cooked. While dried "white fish" made a product with longer storage life, large-scale operations have been devoted mostly to the dehydration of herring for reasons of cost-price and availability of raw material.

Description of Drier

The drier used (British Patent 544,229) is of the tunnel type developed from the controlled smokehouse invented at the Torry Research Station before World War II.

It consists essentially of a chamber holding the four tracks. A 35-inch axial flow fan driven by 10 hp., motor, is fitted into a recirculation duct over the chamber. Two steam heating batteries are provided, one in the recirculation duct and a smaller one in the middle of the chamber between the second and third trucks. The drying chamber is fitted with adjustable diffuser walls at inlet and outlet ends which ensure uniform air-flow over any cross-section. This provision was the special feature of the original smoke-curing kiln. The fan delivers about 30,000 c. f. m. Fresh air is taken in through adjustable louvres placed before the heaters and behind the fan in the duct, and wet air is vented through an exhaust duct at the bottom of the chamber just below the outlet diffuser wall, an adjustable flap giving venting control. The steam heating is controlled by thermostats operating motorized valves. The drier is insulated with magnesia block and is satisfactorily air tight. (Anon. Undated.)

Description of Method

The manufacture of fresh-cooked dehydrated herring as developed for large scale operations at the Torry Research Station is as follows: As soon as the fresh herring are landed they are packed in quarter-cran boxes (about 98 lb.) and well iced. The boxes are delivered to the plant by truck. The first operation at the plant is washing and scaling. The machine used is essentially an inclined drum, made of rods spaced closely together, and revolves in a tank half-filled with water. As the fish are carried through the drum, the tumbling action and the abrasive effect of the rods forming the drum wall remove all slime, scales, and other debris.

The washed fish are mechanically split, gutted, "block" filleted and given a second washing, using special machines each with a capacity of 1½ to 2 crans of fish per hour. The report of the Torry Research Station states that: Four machines are installed, which should easily handle expected full daily capacity of the plant, amounting to about 28 crans required for two drying runs per day. Roes and milts are canned; the guts, bones, and other waste are sent to a fish meal factory. The washed fillets are spread on sheet-metal trays with perforated bottoms, in an amount of about 28 pounds per tray. The individual trays are 29 by 33 inches. The loaded trays are placed in wheeled angle-iron racks which hold 11 cooking trays spaced vertically at 2¼ inches apart. The racks are run into a horizontal retort of the Portland type. A retort will hold two racks. The fish are cooked for 20 minutes at 6 pounds steam pressure (230° F.). The racks of cooked fish are wheeled from the retort to a small tunnel cooler where they are cooled in a current of air at surrounding temperature until the fish reach a temperature below 100° F., which requires about 30 minutes.

When cooled, the cooked fish are emptied into a hopper from which they are fed to a power-driven grinder, using either a ¼- or ⅜-inch plate. The ground material is spread in thin layers on drying trays with tubular metal frames and bottoms of heavy galvanized wire mesh. Each tray is loaded to an average of 2¼ pounds of ground material per square foot of tray area, each tray load being check weighed. Loaded trays are placed in wheeled dryer racks. Each rack has a capacity of 44 drying trays spread 2 inches apart. The dryer holds four racks, the total load of cooked fish being about one ton.

The operation of the dryer is described as follows: The drier is warmed up and after loading with four trucks it is set to run with a supply air temperature of 175° F. with intake and outlet vent open full. The wet bulb temperature rises quickly to about 125° F., then falls gradually thereafter. After 1½ hours the dry bulb temperature is set at 160° F. and held there for the rest of the run which takes about 4½ hours. At the end of this time the dried material, about 900 pounds, having a moisture content normally reduced to 2 to 4 percent is cooled and stored in large covered metal bins for packing.

The dried fish is packed in No. 10 cans, each can holding 3 pounds. To obtain this fill it is necessary to press the fish lightly with a hand-operated pressing machine. The filled cans are sealed by a hand-operated closing machine. The cans are then nitrogen filled, using the same method as in the British Ministry of Food vegetable dehydration plant. The cans are brogued, that is, punctured with a small hole, then placed in gas packing cabinets. Each cabinet has a capacity of 12 No. 10 cans, with wooden partitions. A vacuum pump is connected with the closed cabinet and the air is exhausted until a minimum pressure is reached. This usually requires about 2 minutes. Nitrogen is then admitted steadily, the pressure being raised to 2 pounds per square inch above atmospheric pressure. The "brogue" holes are soldered immediately after the cans are removed from the cabinet. When soldered, the cans are given a coat of outside lacquer and packed in wooden boxes, six to the box.

PRINCIPLES OF FISH SALTING

Salting has been the most important method of fish preservation since prehistoric times. In the United States salting has been displaced almost entirely by canning and freezing. In Canada, these methods now equal salting in production, but in all other countries with fishery industries the quantity of fish salted is far greater than the production of canned or frozen fish.

Salt is used in almost all methods of fish preparation, either as a condiment, flavoring agent, or as an accessory preservative. Many dried or smoked fish are lightly salted or at least flavored with salt, but speaking accurately, only when salt is the principal preservative should the method be called salting.

PRESERVATIVE ACTION OF SALT

Salt is not an antiseptic in the accepted sense of the word, though it is a valuable agent in the prevention of spoilage. Salt preserves by extracting water. If fish are laid in salt, the salt soon removes sufficient liquid from the fish to form enough brine to cover them. At the same time the water is being removed from the fish, salt enters the tissues of the fish and soon the body juices have become a concentrated salt solution. When enough salt has entered to coagulate all the proteins that are coagulable by sodium chloride and when the tissue cells have shrunk because of the loss of a large share of the moisture content, the fish flesh loses most of its translucent appearance and does not feel sticky to the touch. At this stage the salter would say it is "struck through."

The action of the passage of salt into and moisture out of fish flesh is an example of the phenomenon of osmosis. In the osmotic action of salt solution with the juices of the fish flesh, the skin and cell membranes act as imperfect semi-permeable membranes. Dilute cell liquid, mostly water, passes from the fish and the entry of some salt into the cells precludes the withdrawal of the colloidal protein of the cells. The direction of flow of liquid through semi-permeable membranes is always from the weak to the stronger solution. Therefore, when fish are placed in strong brine, liquid passes rapidly out of the cells of the fish flesh, through the cell wall into the brine. On the other hand, salt from the brine slowly passes through the cell walls into the protoplasm. Ultimately a state of equilbrium is reached in which the concentration of the solution inside of the cells of the fish tissue is equal to that of the curing brine. When this point has been reached, the salting action is complete.

FACTORS AFFECTING THE SALTING OF FISH

There are a number of factors affecting the salting of fish which determine the quality of the finished product. The length of preservation is dependent to some extent on variations in these factors. The most important are outlined briefly here. The subject is treated at length by writers cited in this report.

Composition of Salt

Tressler (1923), Boury (1932), Carter (1932), and Reay (1936), have found that the composition of salt is of great importance not only in affecting the rate of penetration, but also in determining the physical nature of the finished product. Common salt is a simple chemical compound composed of sodium and chlorine; its chemical name is sodium chloride. It occurs widely in nature; in the sea and in deposits in the earth. Salt is obtained by mining or by the evaporation of sea water. Salt used for food purposes, however, is never chemically pure sodium chloride as it contains small amounts of other minerals and organic material, as impurities and a small amount of moisture. This is especially true of "solar" salt, that is, salt obtained from the sea. The principal impurities in ordinary commercial salt are calcium salts, such as calcium sulphate; magnesium salts, for example, magnesium sulphate, and organic matter. Solar or sea salts are most widely used for the salting of fish, though more mined salt is being used since Tressler reported his study on this subject in 1920 and 1923.

Salts of calcium, magnesium and the other sulphates retard the rate of penetration of common salt into fish flesh during the curing process. This is more likely to permit decomposition of the protein of fish flesh during the salting process. Therefore, it is important to use the purest salt obtainable when the weather is warm, or under other adverse salting conditions. The U. S. Bureau of Fisheries (now the Fish and Wildlife Service) in a series of experiments measured the rate of penetration, using different types of salts (Tressler 1920). In this series were included chemically pure salt and salts containing various impurities in different known amounts. It was found that a salt containing 4.7 percent magnesium chloride, penetrated no farther in 5 days than pure salt did in 3 days. This is definite proof that a salt free from impurities should be used if rapid penetration of fish flesh is desired.

There is yet another difference in the effect of pure and impure salt in fish salting. It has been found that calcium and magnesium salts have a marked effect on both the color and texture of salted fish. Fish salted with pure salt are limp, soft and have a straw or cream color. Such fish are more easily freshened than the usual commercial salt fish and resemble fresh fish more closely when cooked. If ordinary fish curing salt is used, the texture is much more stiff and brittle and the color is the chalky white usually associated with commercial salt fish of the cod group. It has been found that the presence of as little as one percent of calcium or magnesium in salt causes a remarkable whitening and stiffening of the flesh. Since impure salt has always been used in salting, buyers demand a firm white-fleshed fish. It is believed that the fish cured with pure salt is in every way superior, but the curers must be educated to prepare fish of this description, and the public to buy it. Salts of both calcium and magnesium give the strong, acrid flavor characteristic of commercially salted fish.

Influence of Temperature

Fish are salted over the temperature range of 32° to 100° F. It is the common experience of fishsalters that at the higher temperatures there is very rapid "striking through" or penetration of salt, much faster than at normal temperatures of about 60° F. Fish may readily become oversalted at higher temperatures unless they are dried after a shorter brining time than usual.

It is asserted by Taylor (1922) that cold, approximating the freezing point, also promotes rapid penetration of salt and it is claimed that this has been definitely proved by experiment. On the other hand, unpublished work on the salting of salmon conducted at the College of Fisheries, University of Washington, indicates that the rate of penetration of a 90° salinometer brine at 32° F. is two-thirds the rate at 60° F. A practical proof of the University of Washington data is found in the commercial mild curing of salmon. If the sides of salmon are placed unchilled in the curing brine, they absorb too much brine, which also penetrates too rapidly so that the flesh is over salty and improperly cured. Therefore, the sides are chilled for 2 to 4 hours in a tank of iced 30° to 40° salinometer brine before salting so that the rate of penetration will be delayed. It should also be noted that 39° F. is considered the best temperature for mild curing. Scofield (1925) states that a temperature above 44° F. is not safe for mild curing salmon.

Influence of Method of Cleaning

The preliminary treatment, or butchering and cleaning, varies with the species and size of the fish and the type of product demanded by the market. Some fish, such as certain types of herring, are not cleaned at all, but are salted round. In salting Dutch cure and Scotch cure herring the fish are cut at the throat and the gills are removed so that the blood flows freely and is collected in the brine. The bloody brine gives a distinctive flavor much desired in certain European and American markets. Other small fish are beheaded, split down the back and thoroughly cleaned. Large fish are split into sides or fillets, with all blood, viscera, and other offal completely removed. Salted fish prepared by the last two methods do not spoil so quickly as the first two.

The studies of Tressler (1920) on the influence of different methods of cleaning as applied to the rate of decomposition in salt fish, have indicated clearly that it is essential to remove all blood and offal if decomposition is to be reduced to a minimum. Tressler made a series of experimental packs of salt fish in which fish were cleaned by various methods, and in greater or less degree. Two complete series were made, one held at 79°, the other at 88° F. during the salting process. The amount of amino nitrogen developed was determined by analysis. It was found that the amount of amino nitrogen increased in proportion as the degree of cleaning decreased. The development was greatest at the higher temperature. Only the fish which had been thoroughly cleaned and freed from all blood were salted successfully at temperatures of 79° and 88° F. While high temperatures were chosen for the test to provide a more striking illustration in the shortest time, results will be the same at a lower temperature though the time required will be longer.

Decomposition may occur in blood or flesh, or in both. Since blood decomposes rapidly it is believed that in the work just described, only the blood decomposed and pervaded otherwise sound fish giving a tainted odor and poor appearance. If fish are to be salted in warm weather it is necessary that the blood be removed thoroughly. This cannot be done by eviscerating the fish with the average amount of care and rinsing in water. The diffused blood must be leached from the flesh, and veins. The false kidney which is the dark bloody streak just below the backbone must be scraped out and the fish thoroughly washed in clean water.

Influence of Method of Salting

There has been some disagreement as to the relative merits of dry and brine salting of fish. Northern curers generally use the first method while salters in the Middle and South Atlantic States favor the second. For the purpose of this discussion, dry salted fish are those covered with dry salt and the brine is allowed to form naturally. In brine salting the fish are emptied into tanks containing enough brine to cover them, instead of waiting for the brine to form naturally. Southern packers claim that it takes too long for the brine to form naturally and that deterioration occurs unless the fish are covered immediately with brine. Tressler (1920) also determined the comparative efficiency of these two methods. From his work and that of other investigators it has been determined that brine-salted fish consistently undergo greater decomposition than those cured in dry salt. Tressler found that the average excess of amino nitrogen in six lots of fish pickled in brine over that of six lots cured in dry salt was 51 percent.

Fat fish cannot be exposed to the air in curing. Such fish as cod can be dried in the air either with or without salting because the fat content of the flesh is low. Salted mackerel, herring, or salmon must be kept away from contact with air. If they are not so protected, "rusting" sets in; that is, a brownish discoloration appears on the exposed surfaces and rancidity develops. The fish are soon no longer marketable. Every year much salted mackeral and herring are lost through rusting for this reason.

Because of the development of rancidity and as fat in any appreciable amount retards the rate of salt penetration, it is difficult to salt fat fish successfully and store them over a fairly long period of time. To do so, they must be kept away from both light and air. The use of chemical agents is possible in certain fields to prevent oxidation and rancidity. The Fish and Wildlife Service has done some work on the use of chemical preservatives or reducing agents in preventing rusting and oxidation. None of the agents tested was found to be very effective in the concentrations ordinarily used in other foods. About all that can be done is to make sure that the fish are in tight barrels, are completely covered with strong brine, and held under proper storage conditions.

In addition, the comparative rate of penetration of the salt was determined. It was found that the percentage of salt was higher in both the inner and outer layers of the flesh in dry-salted fish than in brine-salted fish. The rate of penetration of salt is about 20 percent more rapid in dry-salted fish. This is believed to be due to the fact that in dry weather there is always an excess of salt so that the brine is not permitted to fall below the saturation point. This is to be expected in accordance with the effect of osmosis. The flow of liquid in osmosis is always from the less to the more concentrated solution. Brine is weakened rather rapidly by the extraction of water from fish tending to bring the solutions inside and outside the fish into equilibrium and therefore slowing the curing process.

Behavior of Fat in Salting

Fat fish like herring cannot be exposed to the air in curing. If so, "rusting" sets in and rancidity develops. Because of this and because fat retards the rate of salt penetration, it is difficult to salt and store fat fish successfully. All that can be done is to pack the fish in tight barrels, completely cover them with brine, and hold in chill storage. The Fish and Wildlife Service has studied the use of chemical preservatives in salting fat fish. None of those tested was found to be very effective.

Influence of Storage Conditions

The kind of storage is a deciding factor in determining the length of preservation of salt fish. The importance of storage in canning has been stressed elsewhere by the writer (1943) but proper storage is even more essential in fish curing. Salt fish is not protected by a hermetically sealed container. It is liable to more types of spoilage than canned fish. Improper storage may greatly reduce the normal length of preservation of salt fish.

The familiar injunction to "store in a cool, dark place" has been used almost as long as foods have been preserved commercially, and is generally conceded to be a necessary admonition. The reasons for this instruction are among the most important points in successful food storage. In most chemical reactions the speed of reaction increases rapidly with a rise in temperature. It has been calculated that the speed of reaction is doubled with each increase of 18° F. In experiments conducted at the Technological Laboratory of the Fish and Wildlife Service at College Park (Md.) samples of herring stored at 95° F. spoiled twice as rapidly as samples held at 80° F. Salted river herring stored at approximately 40° F. have been held in good condition more than a year whereas herring held at room temperature, about 70° F., spoiled in 90 days. Light, or more particularly sunlight, by itself also hastens the oxidation and hydrolysis of the fat of fish. There may also be a physical softening of the tissue structure. Therefore, salt fish should be stored in a cool, dark place especially if it is fat.

Herring, mackerel, salmon, and any other fat fish are usually held under the surface of strong brine, in chill storage. On the other hand, the enzymic or autolytic deterioration of salt fish flesh is so slow under proper storage conditions that fish will remain in good condition for at least two years. The importance of proper storage in preventing reddening is discussed at length in the section on reddening under the title, Spoilage in Dry Salt Cod and Other Fish.

DRY SALTING COD

On a world basis dry salt cod is second only to herring in importance as a cured product. In this discussion the term "dry salt cod" will include the flesh from various members of the family Gadidae cured by dry-salting. The fish of this family are taken in the same areas, cured by the same method, and the final product is similar. It is also customary in the salt fish trade to include these species with dry-salted cod. Species of Gadidae other than cod are of minor importance as a salt product. These species are also classed together as "groundfish" since they live on or near the bottom. When salted or dried, the groundfish other than Gadidae are generally known as "scale fish."

SPECIES AND RATE OF PRODUCTION

The various species of Gadidae salted in the United States and the estimated proportion they form of the total amount salted are: cod, Atlantic (*Gadus morhua*) and Pacific (*Gadus macrocephalus*), 94 percent; haddock (*Melanogrammus aeglefinus*), 1 percent; pollock (*Pollachius virens*), 3 percent; hake (*Merluccius bilinearis*), 1 percent; and cusk (*Brosme brosme*), 1 percent.

The salting of cod is widely distributed through the north temperate zone. Norway, Newfoundland, Iceland, Canada, the United States, the United Kingdom, France, Portugal, and Spain are the principal sources of salt codfish in about the order named. Unknown but probably important quantities of salt fish are produced in the Union of Soviet Socialist Republics. Some dry salting of cod is also done in Germany, the Netherlands, Sweden, Denmark, and Japan.

The salt-cod industry was at one time the most important fish preservation industry in the United States. At one time more than 80 percent of the catch was salted. The poundage salted and its importance in relation to other fishery industries have both decreased greatly in this country. In 1914 the amount of salt cod produced in the United States was 68,456,917 pounds. In 1919 the amount was 62,902,037 pounds; in 1929, 28,973,492 pounds and in 1940, 17,737,263 pounds. Domestic consumption has not decreased to the degree indicated by the production figures, since the United States has become an importing instead of an exporting country. Imports of salted cod (groundfish, all types) supply about 80 percent of domestic consumption. Imports in 1939 totaled 53,918,000 pounds. Approximately one-half the imports of salted cod or about 23 million pounds are consumed in Puerto Rico and the Virgin Isles. About 95 percent of the imports originate in Newfoundland and Canada.

The decline in the salt-cod industry of the United States is due to a number of factors. The great increase in the production of canned fish has absorbed a portion of the market. The development of refrigeration and the filleting industry has not only diverted a large part of the raw material formerly used for salt cod, but has also taken part of the market. Another factor is the great increase in the price of raw material and other production costs, so that it is no longer an economic method of preservation in the United States, except under special circumstances. Change in food habits is another factor.

GROUNDS WHERE CAUGHT

Cod and related groundfish are found on banks which are submarine plateaus on the Continental Shelf where the water is cool and rich in food material. At certain seasons cod can be found in bays and inlets close to shore. Then they go off to the banks again. There are two types of banks, "inshore banks" usually small, close to shore or between the outer islands; and "offshore banks" found farther out to sea and generally large in area. The Grand Banks of Newfoundland are a good example of the offshore bank. Cod are found at depths of up to 100 or 150 fathoms. Beyond these limits the bottom drops off rapidly to one or two miles, when conditions are otherwise unfavorable. The banks on which cod are found stretch from Long Island to the coasts of Greenland on the Atlantic coast of North America. They amount to at least 260,000 square miles in area which is equivalent to the area of all the coastal States from Maine to North Carolina.

Cod are found on the Pacific coast from Puget Sound along the coast of British Columbia and Alaska extending into the Bering Sea almost

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to the island of St. Lawrence. The Pacific cod banks are reported to be larger and of greater potential production than the Grand Banks of Newfoundland. There are, too, extensive banks off the Siberian coast.

GEAR AND METHODS OF CATCH

Various types of gear are used in taking cod. The otter trawl is most important in the United States fishery, but nearly all of this catch is sold fresh. The trawl line and hand line are the traditional types of apparatus used by salters in the United States, Canada, and Newfoundland. Floating traps, pound nets, and sunken gill nets are also used. Objections made to the otter trawl as gear in catching cod for salting are that the fish are taken in such large quantities that they cannot be handled speedily enough to prevent deterioration before they can be salted. This objection is also made to the use of the trap. The best-quality fish are reported to be those taken by hand line.

HANDLING RAW MATERIAL

Handling of the raw material before it is brought to the plant and placed in cure, largely determines the quality of the finished product. For the best-quality product, the fish should be alive when taken from the gear and bled immediately by the fisherman. This may be done by cutting the throat, pulling out the gills or cutting out the tongues. Some fishermen cut out the tongues as a means of keeping count of the catch and for personal consumption. Bleeding is recommended because diffused blood in the flesh darkens and discolors the tissue, and deteriorates much more rapidly than the flesh itself. It is, therefore, an excellent medium for bacterial growth. Bleeding is, of course, impracticable in handling otter trawl or trap catches but it should be used wherever possible. The Norwegians are most careful about bleeding fish, and this practice is followed by some Canadians, but rarely if ever by curers in the United States.

Some cod has already deteriorated in quality when it is taken from the water because of the type of gear used and the method or lack of method in operation. Weather conditions sometimes affect the operation of gear, and these, of course, cannot be controlled. Since gill nets strangle fish in the act of catching them, the fish have already been dead for some hours when taken from the water, reducing by so much, the time that may safely elapse before they are put in salt. Fish may be left on trawl lines for two or three days especially when stormy weather prevents overhauling the lines. Cured fish from this raw material will have a darker color and the flesh is apt to be broken and loose, especially near the backbone.

Rough handling on the fishing vessel increases the rate of deterioration, making it more difficult to prepare a well-cured product. This is because bruising and crushing of the fish greatly increases the rate of autolytic decomposition. Fish should be carried or transferred by conveyor, not thrown about; it is a wasteful practice to use the pew or one-tined pitchfork to toss fish from the boat to the wharf or into the unloading bucket. The use of the pew or fork is favored by some fishermen as it is an easy method of handling, but it encourages carelessness and pitching, with consequent bruising and crushing, thereby lowering the quality of the raw material. Also important is the fact that the flesh is pierced by a number of holes. These holes are excellent inoculation centers for bacteria, so that the tissue around the holes is soon darkened, and may acquire an off flavor before other portions of the fish. The use of pews should be prohibited as much as possible. If they cannot be dispensed with entirely, the curer should insist that fish be forked only through the head, and laid, not tossed, on the wharf. However, it is advisable to land the fish by other means, such as by hoist or elevator conveyor.

If the fish cannot be put in salt within three or four hours they should be well cleaned, the gills pulled out, and they should be iced. The amount of ice depends on the season; a good general rule is that the fish should be well covered. The cleaning usually given on the fishing boat is apt to do more harm than good. The blood is not scraped out and bits of viscera are allowed to remain. Washing, if done at all, is very sketchy. As a result, deterioration is often more rapid than with round fish, since the flesh is cut open, the bacteria-laden slime can enter, and the blood and bits of viscera are excellent culture media for spoilage organisms. The fish must be thoroughly cleaned and well washed in clean water, if this operation is to delay, not promote, spoilage.

In smaller fishing boats the cod should not be exposed directly to the sun and air, even if the trip to shore is only a few hours. A covering of some sort, such as a tarpaulin should be stretched over the fish, but should not rest directly on them. Space must be left for the circulation of air. Several buckets of clean sea water should be thrown on the fish to rinse off as much slime as possible when they are taken into the boat.

ATLANTIC COAST METHODS

On the Atlantic coast, most of the fish salted in the New England industry are surplus stock from the fresh-fish market. If the demand for fresh fish is light, these fish are sold principally to the fish-curing firms in Gloucester, Mass., or Portland, Maine. The vessel fishery where the catch was salted aboard ship has almost disappeared. Some shore fishermen along the coast of Maine still operate but the fish are cured ashore. The vessel-fishery cure is still carried on in the Maritime provinces of Canada, and in Newfoundland, though even here it is somewhat reduced in size.

BUTCHERING AND SPLITTING

In New England when the fishing vessel is docked the fish are taken out of the crushed ice and pitched into baskets or buckets holding about 2 bushels. These are hoisted out of the hold and emptied on the wharf where the cod are graded into three sizes, large, medium, and small (also called "snappers" and "scrod"). They are then pitched into boxes on platform scales and are weighed. All of this pitching is done by the single-tined forks or pews discussed under handling. After weighing, the fish are forked into two-wheeled carts, taken to the splitting tables, usually located in a nearby fish house, and dumped on the floor.

Then the cod are forked into racks near the end of the splitting table. Here a workman known as a "throater" grasps the fish, holding the head with his left hand, with the belly side of the fish up. He makes a cut through the isthmus and cuts down around the backbone following the curving line just below the gills. The head is held over the edge of the table and is broken off at the first vertebra with a quick snap, leaving a more or less ragged tip. If the fish has not been already cleaned on the fishing vessel it is cut down the belly to the vent, and passed to a "gutter" who removes the viscera. The livers and roe are usually saved.

The cod then go to splitters at the other end of the table. The splitter as a rule, uses a special knife, rounded at the tip of the blade, and with the blade curved slightly, flatwise. With the back of each fish braced against a cleat nailed on the splitting board, the cut made previously for gutting, from the throat to the vent, is continued along the left side of the backbone to the tail, making the cut no deeper than necessary for cutting out the backbone. A horizontal cut is made through the backbone about two-fifths of the distance from the tail and it is loosened so that the splitter can catch the lower end in his fingers. Grasping this with his left hand, he cuts under the backbone toward the head of the fish and separates the forward three-fifths of the backbone from the body, the lower two-fifths remaining. The edge of the knife blade should be held close against the backbone. If this is not done, much flesh adheres to the backbone and is lost. A short, shallow cut is usually made under the edge of the remaining section of backbone, to permit the removal of blood spots and obtain better penetration of salt. When finished the cod should be split evenly along the backbone from head to tail, with the backbone cut, not broken, three-fifths of the way down, with no round tail and no ragged edges, no sliver and no gashes. The difference between good and poor splitting is shown in figure 4.

WASHING AND CLEANING

The split fish are thrown into tanks or vats of clean sea water where they are washed after soaking diffused blood out of the flesh. Sea water is preferred since fresh water tends to soften the fish. Washing is important in determining the quality of the product, and in inhibiting decomposition during curing. Unfortunately, washing,

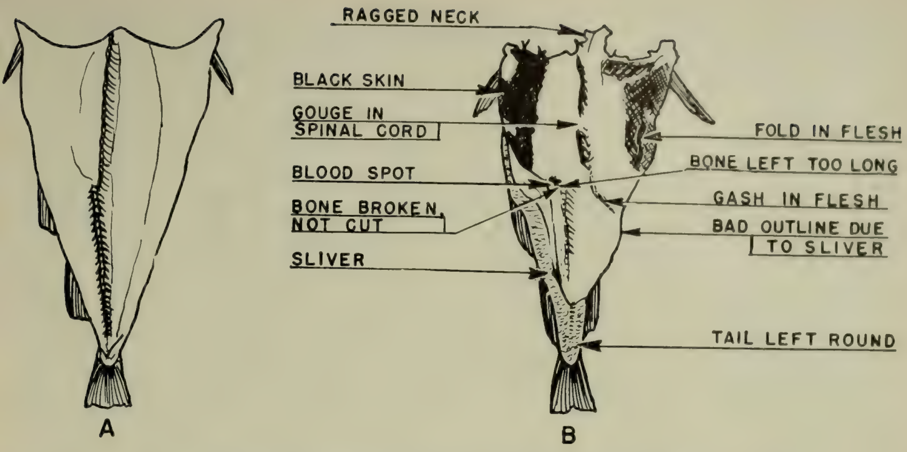

Figure 4.—Splitting cod for salting: (A) Good splitting; (B) poor splitting. (Courtesy Dr. S. A. Beatty, Fisheries Research Board of Canada.)

and cleaning are often superficial and careless. Careful thorough cleaning is essential to a well-cured product. Where running water is not available the standing water should be renewed frequently. Debris and offal accumulate quickly in standing water so that unless the water is changed every few minutes, washing becomes only a process of contamination. A small scrubbing brush should be used on the skin side, and all slime removed, paying particular attention to the area of the back fins. McPherson (1935) states that:

> A brush should never be used for the face of the fish for rough surfaces should be avoided and this can be done with a cloth and plenty of water. The fish should be washed free of all blood and all pieces of gut, in fact it should be in as clean a condition as it would be if it were being prepared for cooking; indeed it is more important that it should be thoroughly clean before preserving than before cooking for the extent of cleanliness affects the preservation more than it would the cooking and eating.

The black lining of the belly cavity known as "black skin" in New England, scrubs off easily in washing. Although removal of the black skin is not essential to preservation the appearance is improved, and for this reason it must be removed if the fish are being prepared for the domestic trade as boneless or for any of the packaged preparations of salt cod. After washing, the fish are loaded on two-wheeled carts to drain while being hauled to the salter.

SALTING

Salting is done in either of two ways, the pickle cure and kench cure. Most of the New England fish are pickle cured, though in winter they may be kench cured. Most of the fish salted ashore in the Maritime Provinces of Canada are pickle cured but all of the fish salted aboard the fishing vessels are kench cured. Some of the shore caught fish in Newfoundland are pickle cured, but much is kench cured.

Pickle Cure

Pickle cured fish are salted in tanks or vats of wood or concrete. Butts or hogsheads, usually old molasses barrels, are often used. These butts are about 3 feet in diameter and 4 feet high. The salters sprinkle a thin layer of salt on the bottom, then place a layer of cod, flesh side up, with the layer level and the fish overlapping as little as possible. Good salting requires skill and experience. The fish will spoil if the amount of salt is insufficient, while an excess results in an inferior flavor and undesirable texture. Small or thin fish require less salt than large thick ones and less salt is necessary in cold weather than in warm. As a rule an even layer of salt thoroughly covering the fish and leaving no uncovered places or finger marks is sufficient. At one time Lisbon (a solar salt from Portugal) or Cadiz was used. Later Turks Island (a salt from West Indies) was favored. Now, however, most New England cures use a domestic mined salt as it is better grade and standard in quality. While fisheries authorities have urged the use of salt by weight rather than measure, this is not often done. The amount of salt used in the domestic pickle cure averages about 17 pounds of salt to 100 pounds of split fish.

The tanks or butts are packed in alternate layers of fish and salt until the level of the rim of the container is reached. The fish are packed about 18 inches to 2 feet above the rim but the last few layers are packed skin side up and a heavier layer of salt is spread on top. As the salt extracts moisture the fish settle slowly and within a day or two sink below the level of the tank rim. It is often necessary to add an additional layer or two of fish at this time. No brine is added, as the extraction of moisture by salt should form sufficient brine. This brine or pickle tests 87° to 97° or an average of 90° salinometer. It should not be allowed to weaken below 90°. When the fish has settled, salt is kept heaped on top not only to keep the cod under the surface of the brine but to make sure the pickle at the top remains fully saturated. The fish are usually "struck" through at the end of about 12 days but are allowed to remain at least 3 weeks. Pickle cured fish can safely be left in the tanks up to a year if the fish are held below the surface of the brine and it is kept saturated (fig. 5).

Kench Cure

The kench cure is used when the cod are salted on board the fishing vessel, or in cool weather ashore. In kenching, a layer of salt is spread on a suitable flat surface, such as the deck of a vessel's hold. There must be good drainage. A layer of fish is then piled flesh side up, in a double row, with tails in and napes out. A thick layer of salt is spread over the layer of fish. The piling of alternate layers of fish and salt is continued to a height of about 4 feet. Two points should be kept in mind in kench salting (1) to make the center higher than the edges so that the brine will drain outward, and (2) to use more salt on thick

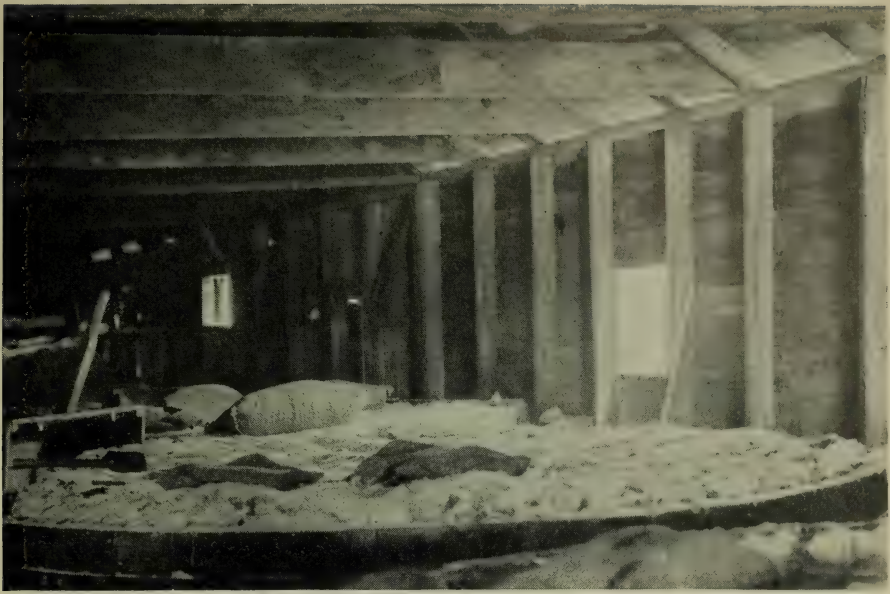

Figure 5.—Salting cod in butts.

fish than on thin ones and with the most salt spread over the thick part of each fish. The fish should also be spread out as flat as possible so that there are no kinks or folds. The top layer of fish is spread skin up (fig. 6).

The amount of salt used in the kench cure varies with the length of time the fish are to remain in the salt, the type of product desired, weather conditions, and the type of salt used. In the domestic industry, using a good grade of solar salt or mined salt, the amount will average about 20 pounds of salt per 100 pounds of fish, though as much as 30 pounds of salt may be used. In Canada, for the kench curing of heavy-salted fish, 100 pounds of salt will be used for about 350 pounds of split fish. In the domestic industry the fish are considered struck in from 14 to 21 days. In Canada the length of time is about the same. In Newfoundland it varies from 10 days to 4 weeks. McPherson (1935) gives 10 weeks as the outside limit, with the heaviest salting, that cod should remain in the kench. Kench-cured fish cannot be left long if the temperature is 60° F. or over, as they soon start to spoil. Kenched fish are also much more liable to discoloration.

DRYING

When the fish are to be dried they are taken from the kench or pickle and washed thoroughly in clean salt water or in brine to remove any slime, dirt, or excess salt. They are piled in kenches (stacks) with the flesh side down, except for the first two layers, on slatted wooden racks from 3 to 9 inches above the floor. These kenches are about 3 feet high. The purpose of this procedure,

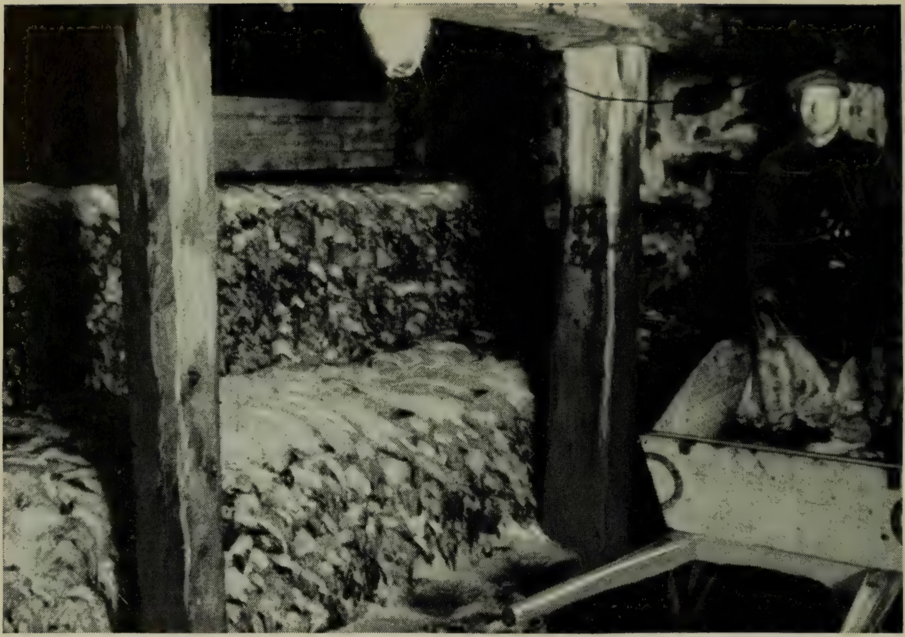

Figure 6.—Salting cod, kench cure. (Photograph courtesy Dr. Olav Notevarp, Norwegian Fisheries Research Station.)

which is known as "water-horsing," is to press out some of the moisture and give the fish a smooth surface. The kenches are often weighted down to press out additional moisture. After 24 hours the fish are often re-piled, but with the layers reversed, that is, with the bottom layer on top. If the weather is unfavorable or if the drying flakes are full, the fish may remain in water-horse for as much as 10 days or 2 weeks. The kenches are torn down and re-piled at intervals as this aids in the drying action and helps to prevent spoilage. If the weather is good and the flakes are nearly empty, 48 to 72 hours water-horsing should be sufficient. The fish are now in the stage known as "green-salted."

Air Drying

The traditional method of drying on the Atlantic coast is in the open air on "flakes." This method is still followed generally in New England and Newfoundland. Improved types of artificial driers have almost entirely replaced open-air drying in the extensive cod-curing industry of Nova Scotia. The Pacific cod fishery of the United States has always depended on artificial driers.

In the New England industry, flakes are latticed frames standing about 3 feet above the floor. They average 8 feet in width and as long as convenient to the location of the drying yard. The bed of the frame is made of triangular wooden strips with a one-inch base, fixed about 3 inches apart. The fish rest on the sharp edges about 4 inches apart, an arrangement whereby the maximum circulation of air about the fish is obtained. The old style of brush flake still used in Newfoundland has disappeared from New England. The flake yard must be located convenient to the saltery. Flakes are often constructed on the roof of the saltery building itself.

If the fish are carefully dried under favorable conditions a much lighter colored product is obtained. Therefore, careful workmanship in drying is essential to prepare a product of the best quality. On hot, bright days a canvas awning is stretched about 3 feet above the flake so that the fish will be sheltered from the direct rays of the sun, which cause yellow discoloration or "sunburn" espeically with freshly spread fish. The fish must also be protected against dampness. When there are signs of wet weather, the fish are gathered in small heaps and covered with flake boxes. These are rectangular wooden boxes with a peaked roof, made of three-quarter inch rough boards and about 22 inches wide, 38 inches long and 14 inches high. A typical flake yard in New England is shown in figure 7.

The amount of drying depends on the grade of fish and the market for which it is intended. Full-pickle fish is dried the least especially if it is to be made into codfish bricks and middles. For the best domestic trade the product must not be too dry. It should retain a moisture content of from 60 to 65 percent. Also salt cod does not skin readily if too dry. Therefore, in favorable weather it is given one drying only. This means about 10 hours of warm sun and good breeze.

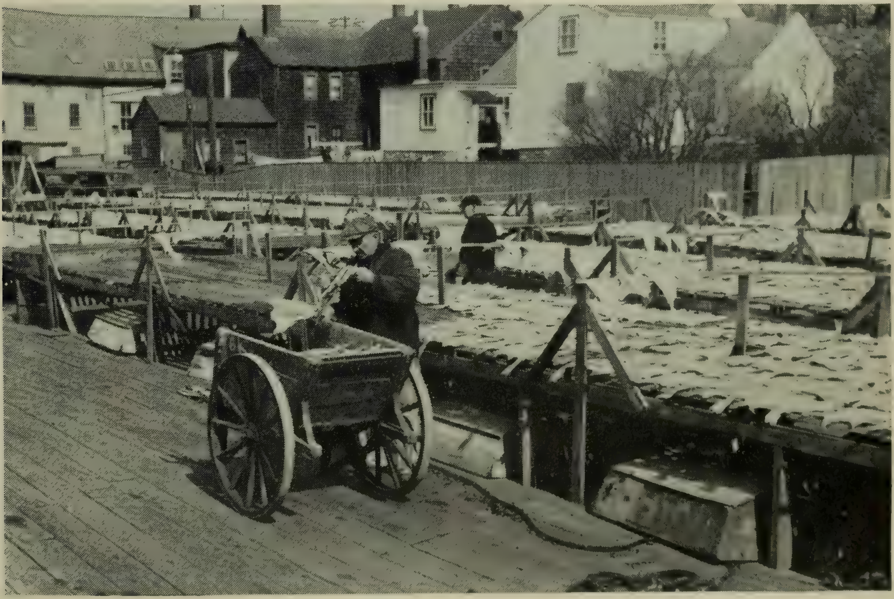

Figure 7.—Drying salt codfish on flakes. (Copyright photograph courtesy Gorton Pew Fisheries Ltd.)

The rate of drying depends on air conditions. According to New England curers the temperature of the air should be about 70° to 75° F. to obtain the best results. The wind velocity should be at least three miles per hour and may be higher, and the air should be less than 70 percent saturated with moisture. The percentage saturation of air at any given temperature is usually called relative humidity. Ideal conditions of air temperature, velocity, and humidity are found only during a part of the year, most often in spring and autumn.

Artificial Driers

Optimum drying conditions may be obtained at any season of the year without regard to weather conditions if an artificial drier is used. Artificial driers have been in use for many years on the Pacific coast and tried experimentally in New England. In Atlantic coast areas of the United States they are, however, used commercially only for special products. In the past there have been objections to the use of the artificial drier in New England. It has been claimed that the fish become case-hardened and do not dry so well inside, that they are more brittle, and that the color is not so good. It is also asserted that fish "scald" easily in these driers. Control of temperature and relative humidity have been the biggest obstacle. McPherson (1935) developed an improved drier but it could be used only with fish already partially air dried. The most extensive studies on the artificial drying of salt cod have been made at the Halifax laboratory of the Fisheries Research Board of Canada. As a result of this work nearly all fish curers in Nova Scotia are using the drier designed at the Halifax laboratory. It is also in use in the remaining provinces of the Maritime in eastern Canada.

For the successful artificial drying of salt fish, it has been found by the staff of the Halifax laboratory, that the minimum air velocity over the fish should be about 200 to 300 feet a minute. Lower velocities decrease the rate of drying. Higher velocities do not increase the rate and only add to the power cost. The optimum air temperature has been found to be 75° F. Higher temperatures than this may cook the fish, while at lower temperatures the drying is too slow. The recommended relative humidity of the air in the drier is from 40 to 50 percent. If the relative humidity does not fall within these limits the rate of drying is slower and the surface of the salt fish is rough, making the fish lower in quality. The investigators at the Halifax Station report that a major proportion of the cost of continuous drying consists of the construction and operation of the dehumidification equipment necessary to maintain relative humidity of 40 to 50 percent during the summer. When the drier is operated only during the cooler months, the cost is relatively low and construction and operation are comparatively simple.

The drier (fig. 8) is of the tunnel type, built of wood with a wallboard lining. It is 28 feet long, 5 feet high, and is divided into 4 bays. Each bay contains 10 trays. made with a wooden frame and covered with chicken wire. A tray is 4 by 5 feet and holds 40 to 50 pounds of boneless or green saltcod. A return air duct constructed on top of the drier enables the air to be recirculated. As a rule, one bay is loaded or unloaded at a time.

According to Linton and Wood (1945):

> The supply fan blows the outdoor air either through the air heater or directly into the drier through a bypass. A mixing damper set in the inlet duct adjusts the relative volumes of incoming warm and cold air to give the desired temperature. The position of the mixing damper is controlled by a damper motor and thermostat. If the temperature of the drier falls below 75° F., the mixing damper closes the bypass and admits more warm air from the air heater. Conversely, as the temperature rises the mixing damper closes the warm air duct from the heater and opens the bypass to admit cool outdoor air. The supply fan admits about 1,500 cubic feet of air per minute and requires a one-third HP motor. The air heater in the present drier is a warm-air furnace, burning coal or wood. Where steam is available, the usual finned steam heater may be used. The obvious advantages of the warm-air furnace are low initial cost, ease of installation, and avoidance of danger from freezing when operated intermittently during the cold weather. The average air velocity over the fish of 250 feet per minute is maintained in the drier by a 42-inch diameter recirculating fan. This propeller fan handles about 6,500 cubic feet of air a minute and is operated by a one-half horsepower motor. The entering warm air is mixed thoroughly with air from the return duct by the propeller fan and the mixture is then distributed uniformly over the fish. Waste air is exhausted to the room at the end of the funnel. The return duct carries about 5,500 cubic feet of air a minute and is large enough to avoid appreciable resistance to air flow.
>
> The relative humidity in the drier depends mainly on the volume of dry outdoor air drawn in by the supply fan.

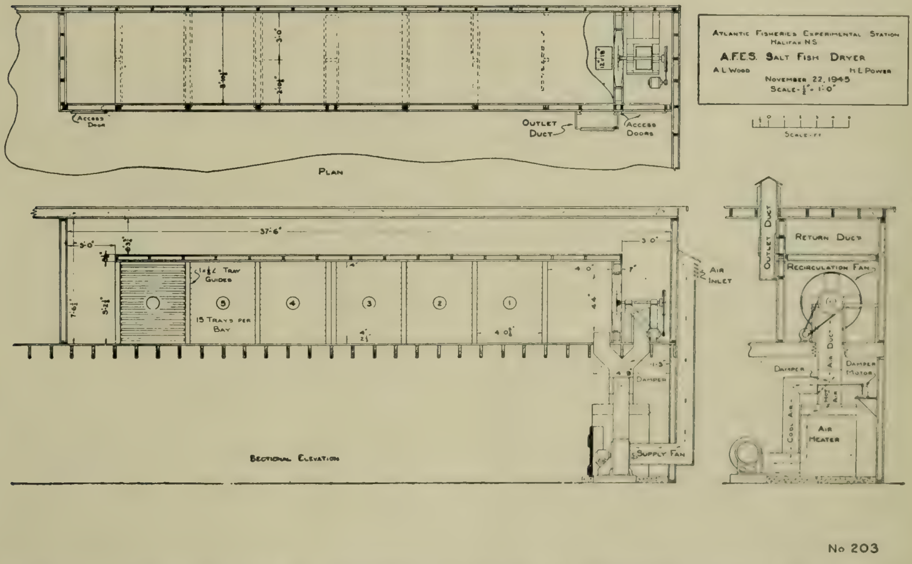

Figure 8.—Plan of artificial drier developed by the Atlantic Experimental Station, Halifax, Nova Scotia. (Courtesy Fisheries Research Board of Canada.)

A hair humidstat, that is, an instrument sensitive to changes in relative humidity, is installed in the drier and starts and stops the supply fan automatically as the relative humidity increases or decreases. If the relative humidity in the drier falls below the desired 40 percent owing to the intake of dry outdoor air, the supply fan stops automatically and as the relative humidity increases owing to evaporation of water from the fish the supply fan starts again. In damp weather the supply fan runs continuously. However, the installation of an ice box for cooling and drying the incoming air enables the drier to be operated.

Water-horsed fish when thoroughly struck contain from 58 to 59 percent water. This moisture content must be reduced in the drier to about 53 percent for one-pound packaged, boneless fish and to about 48 to 50 percent for boxed, boneless strips or middles. Salt cod dried for export should have a moisture content varying from 35 to 43 percent depending on the market for which it is prepared. In the drier just described boneless salt-cod fillets require from 7 to 15 hours to dry depending on the size of the fillet and the moisture content desired. Export or hard-dry fish take about 40 hours. This drier will hold from 1,500 to 2,000 pounds of green salt fish and thus has a capacity of about 1,500 pounds of boneless or 350 pounds of hard-dried cod in a 9-hour day.

PACKAGING SALT COD

A considerable amount of the salt cod now packaged in the United States is cured in Canada, then imported as green salt fish into the United States, where it is dried, skinned, and boned.

Skinning and Boning

Fish intended for the better grade retail trade in the United States are skinned and boned. From the warehouse or flake yard the fish are taken to the "skinning loft" where they are first graded for quality and size. The best quality cod are thick, of a clear, uniformly white color, no blood stains or gashes, a smooth surface, and have a "sweet" odor. In warm weather or if the fish must remain in the skinning loft for some time, they are dusted with fine salt containing 0.4 percent boric acid. This is used as a preservative and as an inhibitant against reddening.

The first step in skinning and boning is to remove the dorsal and ventral fins. The workman starts skinning at the nape, pulling the skin loose towards the middle of the back, after which it is pulled back down to the tail. If the fish has been properly cured, the skin can be stripped clean without tearing the flesh. The nape bone is removed with a small iron hook known as a "bone hooker." This implement is about 8 inches long with a curved shank and sharp point. The tail is cut off, after which the fish is turned over, cuts are made under the edge of the section of backbone still embedded in the flesh, so that it can be removed, and the pectoral fins are cut off. Formerly, these fish were called boneless, but under a ruling of the Food and Drug Administration the fish must be entirely bone free so they are passed to other workers who remove the small rib bones with pliers. The fish are then trimmed, cutting away any stained, discolored, or ragged sections, and are ready to be made into codfish bricks or the various styles of packages distributed to the trade.

Making Codfish Bricks

The method of making codfish bricks described by Stevenson (1899), Cobb (1926), and others, is still used in the smaller plants and in making bricks from hake or pollock. The larger packers have made some changes in the preparation of codfish bricks, speeding up production. This process of packaging codfish bricks in a large United States plant is briefly as follows: Skinned and boned fish of good quality are carried to a cutting table which forms the opposite side of the packing table. Here they are cut into pieces of the proper length. Several fish can be laid on top of each other and cut at one time. They must be placed carefully, however, so as to secure the best cuts from the thick parts along the back. These thick pieces are sometimes split in two to make good outside pieces for the brick (figs. 9 and 10).

After cutting, the pieces are sorted roughly and placed in small bins running down the middle of the packing table. A conveyor belt brings empty molds down the packing table. Each mold is of a size to hold one pound of fish. Girls working at the packing table take the empty molds. One large piece of fish is selected to serve as the bottom and one side, and is placed in position. The center is filled in with small strips. Then another piece is packed in acting as the top and other

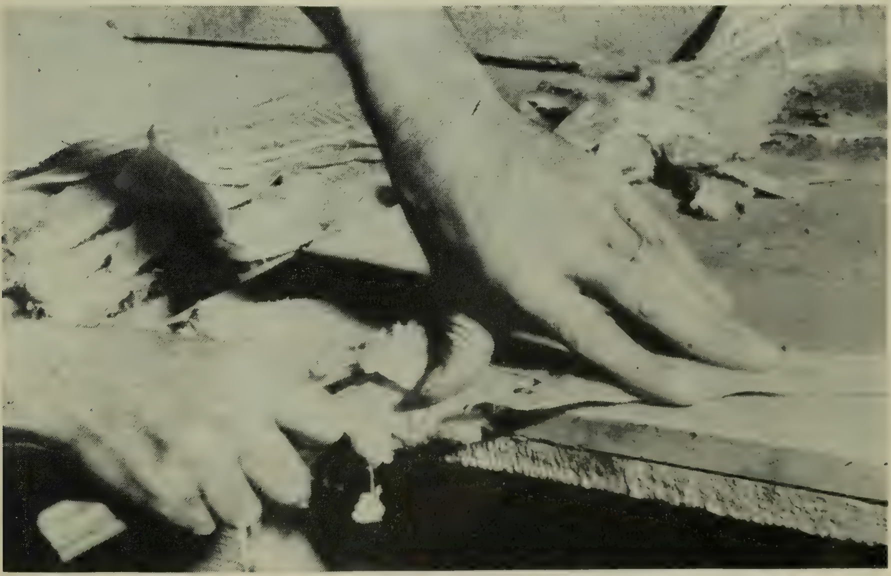

Figure 9.—Splitting salt codfish for bricks. (Copyright photograph courtesy Gorton Pew Fisheries Ltd.)

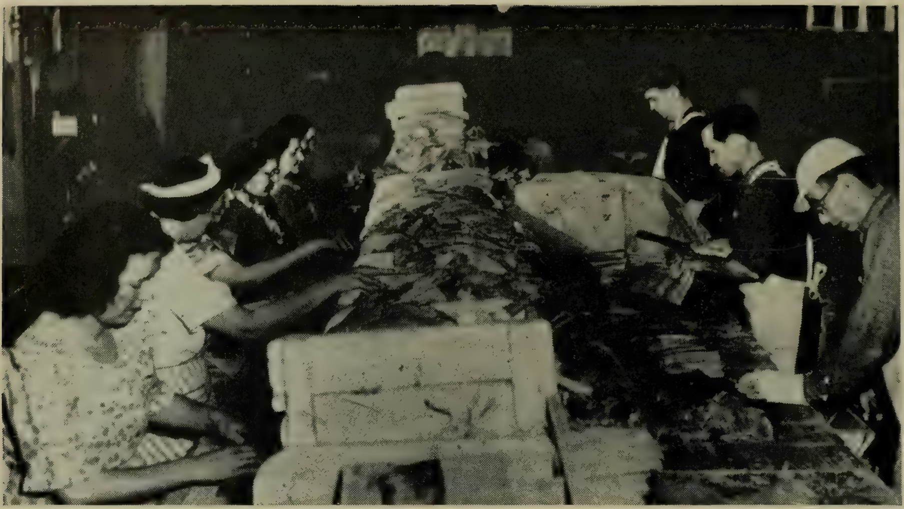

Figure 10.—Preparing codfish bricks. (Copyright photograph courtesy Gorton Pew Fisheries Ltd.)

side. The filled mold then travels down another conveyor belt to a revolving turret type mechanical compressor. Here the fish in the mold is compressed to such an extent that it may be removed from the mold as a solid brick. The bricks travel from the pressing machine along a conveyor belt to a wrapping machine. En route women remove the molds and inspect the bricks for imperfections. A covering of vegetable parchment paper is placed on the bricks in the wrapping machine from which they pass to a packaging machine where they are placed in lithographed pasteboard cartons. The cartons are then packed in cases, usually 24 one-pound bricks per case.

The older method is almost entirely an individual hand-pack operation. The most usual of the older types of presses for making codfish bricks consists of a sliding metal box having two or three compartment molds 6 inches long by 3 inches wide by 3½ inches deep. This will take a two-pound brick. The length and width are the same for one-pound bricks, but the depth is 1¾ inches. When the mold is slid into position a die operated by hand or foot pressure is forced down into the mold, compressing the fish. The molds have either two or four slots in the sides. Cotton strings are run through the slots so as to pass under and around the block of fish. The strings are placed in position in the empty mold after which the brick is packed. The method of packing is as described in the preceding paragraph, except that the pieces for a brick are all selected and weighed before packing. When a mold is filled it is slid into place under the die. The brick is then tightly compressed for a few minutes. While it is under pressure the number two mold is packed. The strings are tied on number one, the pressure is released and the brick is removed. Number two is then placed under pressure while number one mold is packed, and the brick maker proceeds as before. The finished package is then wrapped by hand in vegetable parchment paper and placed in an individual lithographed pasteboard carton.

Bricks are also hand packed in wooden cartons holding one, two, or three pounds. Selected fish is packed as described in the wooden dovetailed boxes previously lined with vegetable parchment or waxed paper. The fish is then pressed down with a hand tamper (fig. 11), the paper is folded over the top and the cover is nailed on.

Shredded Cod

Another packaged salt cod product is "shredded cod," also sometimes known as "fibred codfish" and flaked codfish. The salt fish used for its manufacture is usually whole fish of the same grade as is used in making bricks, fish of good quality, but too small to use in bricks. The fish are dried somewhat more than for boneless fish and all bones are removed. A quintal (112 lb.) of pickle-cured fish will make about 60 pounds of fish ready for shredding.

The pieces of fish are first run through a shredding machine which tears the flesh into small, fibrous bundles. The moisture content must now be reduced from approximately 60 to 40 percent in an artificial drier. Several types of these driers are in use, mostly cabinet or tunnel driers of varieties used for many years in the drying of vegetable foods. Most of these are batch operations, have low capacity, are more or less difficult to control, and

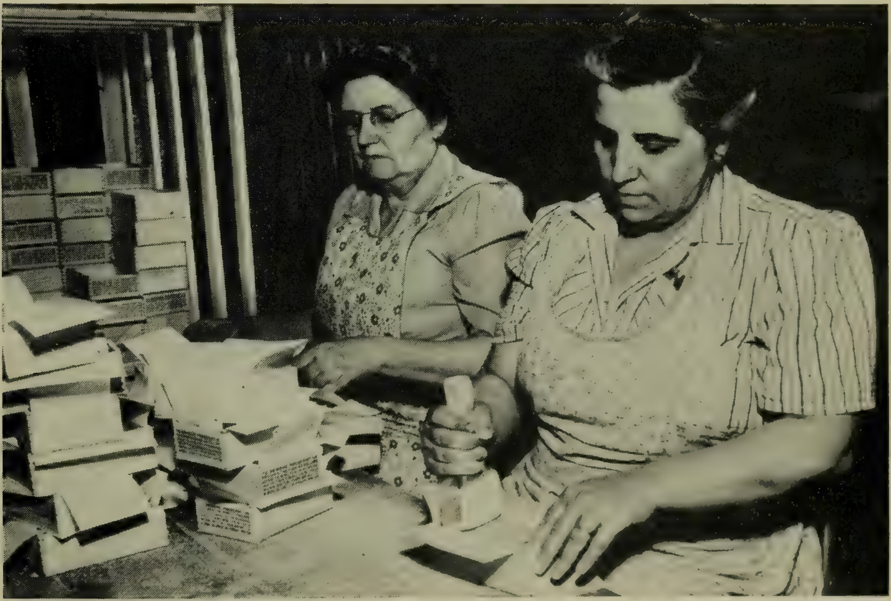

Figure 11.—Handpacking 1-pound wooden cartons of skinless and boneless cod. (Copyright photograph courtesy Gorton Pew Fisheries Ltd.)

are expensive to operate. One large fish curing firm has developed a continuous drier designed to overcome these objections (Burton 1943).

The drier is of the tunnel type. The shredded fish enter the upper section of the drier through a screw-feed conveyor, falling on a conveyor belt of stainless-steel wire cloth. The fish first pass under two sets of revolving paddles which spread the shredded material over the belt. The conveyor belt then passes under a battery of infra-red lamps which heat the shredded codfish to about 150° F. Air is blown through the material from ducts below the conveyor belt driving off the moisture extracted by the infra-red lamps, and preventing over-heating. After passing the first battery of lamps the fish drops to a second conveyor belt where it is spread out by revolving paddles (fig. 12). The operation of the first stage is repeated. After passing under the second group of lamps the shredded fish passes under three electric fans installed for cooling effect and to remove additional moisture. The dried material drops from the end of the belt into boxes in which it is carried to the packing table. It is hand-filled into wax-paper-lined pasteboard containers to a net weight of 4 ounces. This drier has a capacity of 4,000 to 4,300 pounds a 7½ hour operating day.

Shredded cod is also packed in 5- and 7-ounce glass tumblers. The fish is first sifted to remove stray particles of bone, then filled into the containers either by hand or machine. The jars are fitted with metal tops and sealed in a vacuum closing machine. This product is not heat sterilized but due to the low moisture and high salt content it should keep for about two years. The glass tumblers should be kept from strong light to avoid oxidation which causes loss of flavor. Shredded fish is used principally for making codfish cakes.

Strips and Middles

Skinned and boned cod are also packed as "strips" and "middles." Strips consist of one-half the fish cut down the middle. The napes, tail, and edges are cut off leaving an even thick piece of salt fish. This not only improves the appearance but fish may be packed more solidly in the shipping container. Strips are packed in 10-, 20-, and 40-pound wooden boxes. Middles consist of the whole fish with the napes, tail, and thin part of the belly flesh trimmed away leaving one large piece of thick flesh. Middles are packed in boxes of the same size as strips. In the same class is skinned cod in 100-pound cases. This pack consists of the finest whole cured cod, skinned and boned. It is graded according to the number in the case, usually as "large whole" or "extra large whole."

Hard Dry or Export Cod

Cod intended to be marketed in the Southern States or for export is dried to a lower moisture content than for the domestic trade. Either pickle- or kench-cured fish may be used. A larger percentage of the moisture is removed with salt in kench curing, and the fish are re-

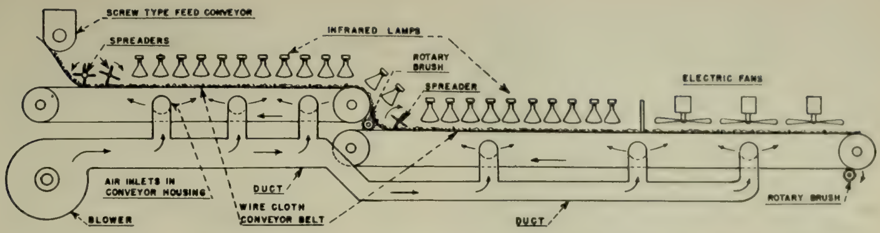

Figure 12.—Diagrammatic sketch of an artificial drier for shredded cod. (Copyright photograph courtesy Food Industries.)

ported not to make so good a dried product. The fish are taken from pickling tanks or kenches, washed in sea water, water-horsed and set out to dry on flakes as described previously. These are dried for 3 or 4 days, then taken in and piled in kenches to "sweat." Moisture is brought to the surface from the inside largely by pressing. The fish remain in the kench for 2 or 3 days after which they are again spread on the flakes to dry for a day or two. The cod are then repiled in kenches and sweated for 3 or 4 days. After a third drying of 2 to 5 days they should be ready for packing. This fish product is known as "hard dried" or "export cure." Some use of artificial driers is made, particularly at seasons of the year unfavorable to air drying. No accurate determinations of moisture content are made but the appearance and texture are noted carefully from time to time. The export fish is usually ready for packing when dried sufficiently hard to withstand the pressure of the thumb in the thick part of the flesh without retaining the impression and there is no visible moisture in the fin folds.

Hard dried fish are packed in drums, boxes, bales, or bundles as the order may require. The regular drums, the package mostly used for export, have net contents of 50, 100, 200, 300, and 448 pounds. The 448-pound drum is the most popular size; 100-pound boxes are also coming into demand. When packing in drums, several layers of fish are carefully arranged on the bottom in circular fashion with tails to the center and flesh side up. Then a single layer is packed skin side up. The cod are then tamped thoroughly with a heavy wooden tamper. Several more layers flesh side up and a single layer skin side up are packed in and the tamping is repeated. The alternate packing and tamping is continued until the drum is filled. It is necessary to pack several inches above the top of the drum to obtain the required net weight, and a jack screw or hydraulic press is required to press the fish down sufficiently for the head of the container to be put in place (fig. 13).

LIGHT CURES

Slack Salted Cod and Pollock

Some of the shore fishermen of the Maine coast prepare small quantities of salted cod and pollock for local use, mostly in October and November. This product is known

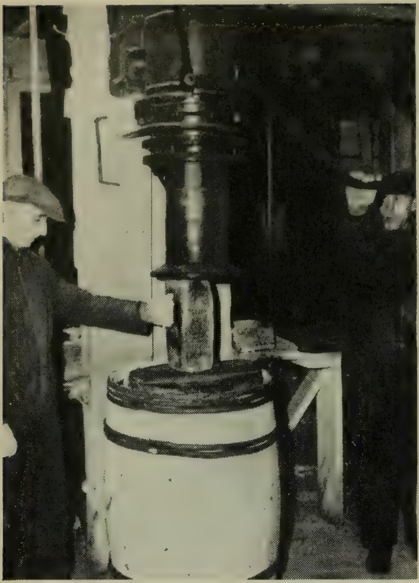

Figure 13.—Packing salt cod (export cure) in drums, Canada. (Photograph courtesy Dr. D. L. Cooper, Department of Trade and Industry, Fisheries Division, Nova Scotia.)

as slack salted. The fish are caught near shore and are headed, eviscerated, slit, and washed on shore. They are "corned," that is, very lightly salted by being packed in salt from 12 to about 48 hours. The fish are then rinsed, and hung from over-head beams in a fish house or warehouse where there is good cross ventilation. They are left here until rather hard and dry. While this product is lightly salted it is dried even more than for the export trade. The flavor is stated to be superior to the ordinary commercial grades. It is sold entirely in the coastal towns of New England.

Gaspé Cure

The best known of the mild cures is the Gaspé cure prepared mostly on the Gaspé Peninsula of Quebec, but also at Caraquet, in New Brunswick, on the Magdalen Islands, and in certain parts of Newfoundland. It is considered to be a high-class product and at one time had a good market in southern Europe, especially in Italy. Some Gaspé cure fish are imported into the United States for sale to the Italian-American trade and the French-Canadian trade of New England.

PACIFIC COAST COD INDUSTRY

Cod only are cured on the Pacific coast. Haddock, hake, cusk, and pollock are not present. The Pacific cod banks have never been fully explored. The known areas are larger than the Grand Banks of Newfoundland, but there are extensive sections where occasional catches of cod have been reported which have never been thoroughly explored or fished commercially. While cod are found in the eastern Pacific from Oregon northwards they are taken for curing only off the coast of Alaska.

As a result of the enormous demand for protein food during World War I there was a boom in the Pacific cod fishery, and the catch rose to about 30,000,000 pounds annually from 1914 to 1918. In the postwar depression of 1921–22, it declined to 9,000,000 pounds, gradually increased to 24,000,000 pounds in 1926, decreased to 16,000,000 pounds in 1927, remaining at approximately that level for the next 10 years. The California fleet abandoned the Alaska cod fishery in 1938 and it then declined to a level of 10,000,000 pounds, where it remained until 1942. In that year, the cod-fishing grounds became a war the-ater, most of the vessels were taken for war purposes, and only one vessel was able to fish. There was no cod curing in the Pacific in 1943, other than the very minor operations of a few shore stations. A single vessel operated in 1944 and 1945. Salt codfish is being shipped from the Atlantic coast in carload lots of whole fish, generally to firms which formerly packaged and merchandised Pacific coast salt cod. The postwar status of the Pacific salt cod fishery depends on the anticipated greater exploitation of fisheries in Western Alaska by shore stations and factory ships. At present, a once flourishing fish-curing industry has almost disappeared—a war baby of World War I, a casualty of World War II.

The methods of the Pacific cod fishery and the salt-cod products prepared, generally resemble those of the Atlantic coast, but there are a few important points of difference. In the first place, in the Pacific the hand line is used almost entirely, to the exclusion of other forms of gear. Secondly, practically all of the cod are cleaned and salted either on board the ship or at shore salting stations in Alaska and are later transported to the home station in the State of Washington, where the fish are dried and packaged for distribution. The vessel-caught cod are not iced, as are those caught on the banks of the Atlantic coast, but are salted in kenches in the hold of the ship. Those caught by the fishermen near the shore stations are salted in tanks at the station but are later shipped to the States for drying. The drying is done principally in artificial driers. The amount of salt used in curing is appreciably greater on the Pacific coast. As a rule from 25 to 30 pounds of salt per 100 pounds of fish are used in the tank or pickle cure. In the kench cure of the vessel fishery the amount of salt averages from 35 to 40 pounds per hundred. The history, statistics, and methods of the Pacific industry are given completely by Cobb (1926). His publication should be consulted for additional detail.

DRY SALT COD—FOREIGN CURES

FRENCH METHOD OF CURING COD

Bordeaux is the center of the French cod-curing industry. Some of the salt cod used in France is cured on the islands of St. Pierre and Miquelon. The method is much like that used in Newfoundland. Most of the catch, however, is salted on board the fishing vessels on the Grand Banks and brought to France to be cured. The fish kenched in the hold of the fishing vessel are transferred to warehouses ashore where they are held in bulk with some additional salt between the layers of fish. The cure is completed as orders for dried fish are received.

Splitting and Salting

In splitting, the French allow more of the backbone to remain in the fish than other curers. Therefore, to remove the blood under the section of backbone left in the cod they use a long-handled iron spoon as a blood scraper. The fish are always washed thoroughly in clean sea water after splitting and before being put in salt. The amount of salt used is reported to average one kilogram (2.2 lb.) to two kilograms (4.4 lb.) of fish. Dieuzeide and Novella (1942) give the amount of salt as one kilogram of salt per kilogram of fresh fish. This includes salt used for all purposes, including the preservation of bait and for repacking. A solar salt manufactured on the French Mediterranean coast is used.

Construction of Drying Racks

Instead of air drying with flakes or on rock-covered beaches, the Bordeaux curers use vertical racks from which the fish are hung by the tail. This type of air drier is practical because it takes up little space, the cure is finished in a short time, varying from 2 to 6 days, the labor used is reduced to a minimum, and the product is of excellent quality, although it does not keep so well as that cured by some other methods.

The racks are constructed as follows: A number of posts are driven in the ground vertically in a straight line from west to east and about 4½ feet apart. Two rows of laths are nailed along this line of posts, just far enough apart to allow the tail of a codfish to be pushed between them. Small cleats of wood are nailed across each pair of laths to keep them from springing apart, the laths are ⅜ to ⅝ inches thick and 1½ to 2 inches wide. The construction of these drying racks may vary slightly. Some are built in square compartments with laths fastened alternately on the north and south sides of the posts and with an alleyway about 2 feet wide between each row of compartments. On other racks, the laths are all fastened on the north side of the posts and each row of racks is set 3 yards apart, in order to prevent the shade from the row in front reaching the one behind (fig. 14).

Drying

The cod are rinsed thoroughly and scrubbed to remove any traces of dirt or encrusted salt. After draining for a short time they are carried out to the racks. The tail of each cod is shoved in between the laths from the north side, with the back or skin side turned upward. The fish will bend down by its own weight and the face or flesh side will be turned toward the sun while the tail is jammed between the laths. When the fish are getting a little dry they will hang in this way even in a strong breeze. Some curers set a straw-covered thatched roof over their racks if the sun is at all hot. Others use no shade covering, but if they think that the sun is likely to burn the fish, the fish are twisted slightly so that the edges instead of the flesh sides are turned to the sun. In damp or rainy weather or when the sun is too hot, the fish must be taken down and stored in the warehouse. In the French codfish cure, the fish are not pressed at all during the drying. After hanging on the racks from 2 to 6 days, depending on the size and on weather conditions,

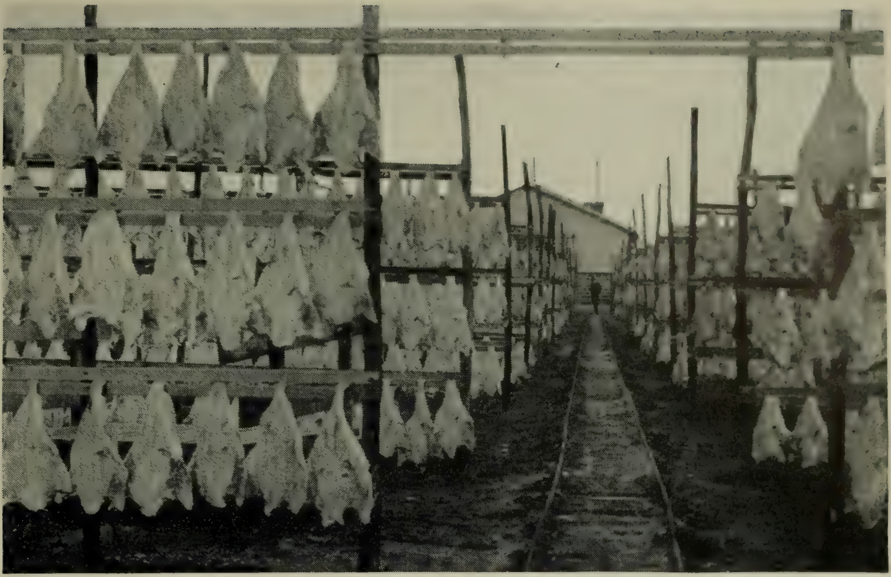

Figure 14.—Air-drying salt cod; French cure. (Photograph courtesy M. Besnard, St. Maur, Seine, France.)

the fish are taken down and shipped to market.

While air-dried fish are preferred, artificial driers are used to some extent because of the uncertainty of natural drying conditions. Driers are of the tunnel type, 25 meters (82.5 ft.) in length, 3 meters in diameter (9.9 ft.) and 2 meters (6.6 ft.) in height. The cod are placed on movable racks, which are run into the drier. The cod are dried in a current of air at approximately 30° C. (86° F.). Length of drying time varies from 3 to 48 hours, depending on size of fish and type of cure (Fillon 1929; Boury 1932, 1934).

ICELAND METHOD OF CURING COD

The Icelanders conduct most of their cod fishery in the open sea at a short distance from shore. The fishing grounds are close to the curing location, sometimes a distance of only a few hundred yards, with a maximum of about 60 miles. In no event are the fish more than 24 hours old when landed. Their fishing craft are principally motor cutters sometimes 5 tons or less, but more often are 80 to 100 tons in size. The fishing gear used consists of long lines, gill nets, and Danish seines. Fish taken by large trawling vessels using the otter trawl are occasionally used for salting, especially since the end of World War II.

Splitting and Washing

As soon as the fish are caught they are bled, usually by cutting the throat. When the cod are brought ashore they are gutted and split as soon as possible. The Icelanders split their fish differently from most other curers, in that the section of the backbone allowed to remain is on the right-hand side instead of the left. The backbone is cut slantwise over two joints instead of being broken straight across, which is thought to improve the appearance. The last 18 to 22 vertebrae remain, the number varying with the size of the fish. The Icelanders also split their fish very deep. After the fish are split they are washed thoroughly in large quantities of clean salt water and scrubbed with brushes to remove all black skin, blood, and other offal.

Salting

The salting is done in sheds where the fish are allowed to drain until all surplus moisture is removed. The drained cod are salted in kenches, using about 40 pounds of salt to 100 pounds of fish. The types of salt favored are: Torraveja, St. Pola, Cagliari, and Trapani. After the fish have been held in salt for 2 or 3 days they are resalted in new kenches, using very little salt this time, only about ⅛ of the former amount. They are left in the second kench for 5 or 6 days, when the fish are ready to be washed and dried, if the weather and season of the year are suitable. Fish caught too late in the fall to be "made" before the next year are salted so heavily in kenches that one fish does not touch the other. If properly washed and cleaned, and all blood removed, it is claimed that this fish will, in the following spring, be of about the same quality as if caught that season.

Drying

After the fish have been held the proper length of time in salt, they are washed thoroughly, and piled in small heaps until all surplus moisture has been removed. When the flesh feels slightly stiff the fish have been sufficiently drained. As a rule, 24 hours are required. If the weather is fair the fish are spread out to dry. If the day is unfavorable the cod are relaid, flesh side down, in square piles, from 100 to 150 fish in each pile. The fish are repiled each day as long as bad weather lasts. On the next good day they are again taken out to dry. The fish are spread on the rocks, flesh side up. Flakes or other types of drying platforms are not used.

Pressing

When the cod have had two good days of sun drying they are stacked in piles, and the cure continues much as in the Norwegian method, weighting the piles of fish more heavily as the cure progresses. When the fish are at the stage the Icelanders call "three parts dry" they are stacked in large piles, with about 7,000 pounds of fish in each pile. These piles are covered with mats or boards which form a roof, and are weighted down with enough rock to correspond to the weight of the fish in the pile. The cod are allowed to remain in these piles for 5 or 6 days, then spread out to dry for a day. At night they are gathered into big piles again and once more pressed down with a weight equal to that of the fish in the pile. This process is repeated until the fish are considered cured. If, because of unfavorable weather, the fish cannot be spread out after they have been put in the first large pressing pile, they are repiled every day and the same weight applied until they are considered cured.

The Icelanders use this heavy pressing in their codfish cure for these reasons: (1) The climate is damp and not very warm; as a rule the sun is seldom hot enough to burn the fish, although this may happen occasionally, and the weather is mostly cloudy or foggy; (2) their fish are heavily salted; (3) the fish are rich and thick, and stand a good deal of pressing.

Since the climate is chilly and damp, pressing is very important, and curing is accelerated by frequent pressing and repiling of the fish. The Iceland cod have taken away much of the Mediterranean market from Newfoundland and Nova Scotia because of good appearance and better quality. Though the fish are always a little pliable and are not cured so hard as Newfoundland and Norwegian fish, Iceland fish keep well in hot climates and are preferred to the hard-cured fish because they are less apt to become brittle and break. Fish cured in the early spring or fall when the climate is chilly are, if sufficiently pressed and salted, superior to the hard-cured fish of the summer season and, even if a little pliable, will keep well in hot climates.

NORWEGIAN METHOD OF CURING COD

The Norwegian dry-salted cod have acquired a good reputation for quality because of the care taken in curing and grading. They are known as "klipfisk" in Norway, and are so-called because they are dried on the rocks or "klippe" along the shore. The curing of klipfisk is an old established industry of great importance to Norway. Very large quantities are cured each year. Much more cod is prepared as klipfisk than stockfish. They are exported to France, Spain, Portugal, the Mediterranean, Central and South America, and the West Indies.

The largest production of the cod fishery is obtained on the northern coast of Norway, Lofoten being the center of the fishery. The fishing vessels sail north each year. The fish are salted on board, and later taken south to the drying areas. Some of the larger vessels sail to the Lofoten area, buy small lots of salted fish from the fishermen and sail south when they have obtained a cargo. The splitting, dressing, and salting are about the same as in the American vessel fishery; that is, they are cured as in our kench cure. The Norwegians are more careful in washing, however, and wash the fish once before and once after splitting. Cleaning is very thorough, especially in the removal of bits of coagulated blood or liver which might cause souring.

Salting and Washing

The fish are drained for about 2 hours after the second washing and before salting. The drained, split cod are salted in kenches about 3 feet in width, and the same in height. The salt used is generally Liverpool, Torraveja, Cadiz, Lisbon, Cagliari, or Trapani. The amount of salt used varies to some extent with the size and thickness of the fish, the type of salt, and the season. The fish are salted fairly heavily, but not quite so heavily as in the Iceland cure. The average is about 35 pounds of salt to 100 pounds of fish. The cod must remain in the kench from 25 to 30 days before they are ready for drying. The cod may remain in salt as much as 2 months.

The drying and pressing are usually done on the rocks in the vicinity of Christiansund and Aalesund on the "klippe." These are various stretches of smooth, white, clean rocks near the seashore (fig. 15). When the fish are taken out of salt they are washed thoroughly in sea water. This is usually done at the beach nearest to the drying place. From 45 to 50 fish are thrown into the water at one time. No attempt is made to handle more than this number or the fish will be freshened too much, the sea water leaching salt from the flesh. In washing the fish, woolen mittens are worn. The fish are again washed carefully to remove excess salt on the surface, or other debris, and are brushed thoroughly to remove blood spots or pieces of black skin.

Drying

After washing, the fish are stacked in kenches about 18 inches in height. The pile is something like a low rick of cord wood. The bottom row of fish is laid skin side down with the other rows skin side up. The stack is usually covered with boards or canvas as protection against rain or sun. On the second or third day, the fish are restacked, reversing the order of the layers. On the third or fourth day, the fish are spread out on the rocks and given about 8 hours of air drying. No particular system is followed in spreading, the fish being simply laid flesh side up on the rocks, with no two fish touching. The first day of drying must be chosen carefully, for if the sun is too hot, a crust will form on the surface, preventing the removal of moisture from within, so that the fish deteriorate.

After the first drying period the fish are stacked skin side up in round piles of 500 fish each. The diameter of a heap is about four feet. The piles are built highest in the middle so that the rain will run off. Care is taken to lay the fish out smoothly to prevent wrinkling. After two or three days of drying, the fish are usually stretched well, especially in the belly section, before being stacked, to remove all wrinkles and to give the fish a smooth appearance. This work is very important, not only to appearance but for longer preservation, because moisture always gathers in the wrinkles and is very difficult to remove entirely unless done in the early stages of the cure. Stretching is slow work but it is considered better to devote one day to it rather than to do it in a hurry in the evening when the fish are gathered in heaps for the night.

Pressing

When the fish have had two or three days of air drying they are stacked in round peaked heaps as before, except that the heaps are larger, with 1,000 fish in each pile.

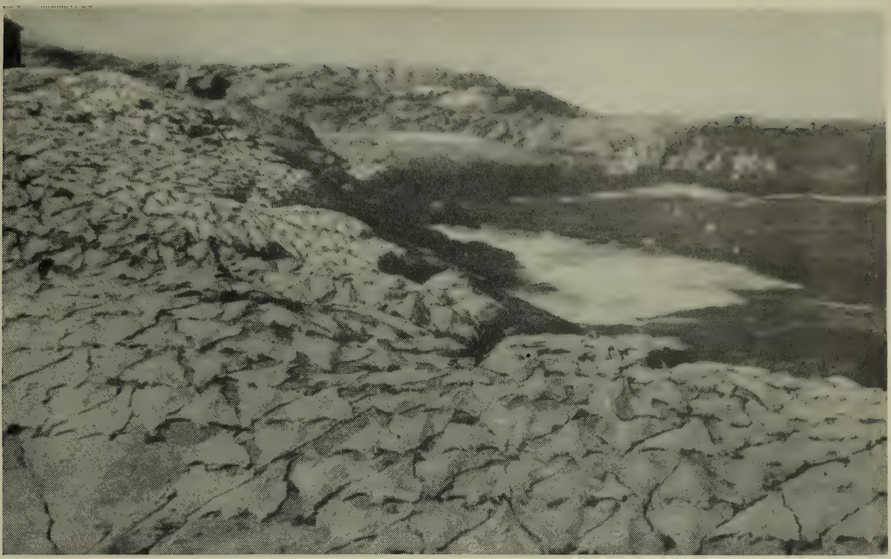

Figure 15.—Klipfisk spread out to dry in Norway. (Photograph courtesy Dr. Olav Notevap, Norwegian Fisheries Research Station.)

The diameter of each heap is still 4 feet, but the pile is higher. The fish are allowed to stand for 2 days, then given another day's drying on the rocks, after which they are re-piled and held for 2 days. The alternation of 2 days of pressing followed by a day of drying is continued until the fish have had about 60 hours of good air drying. They should then be sufficiently dry. If there are spells during the curing period when the weather is not suitable for drying, the fish must be re-piled as often as possible, reversing the order every time they are re-piled. This is done because pressure extracts a certain amount of moisture, enabling the cure to continue, and to prevent the fish from becoming slimy.

Each pressing pile is covered with a small, round, peaked roof of wood about a foot larger in diameter than the heap of fish. This keeps off rain and acts as an added weight for pressing. Stones are placed on top of the roof to aid in pressing, but not to the same extent as used in Iceland. The best fish are said to be made by a long slow drying. Under favorable conditions the usual time required to dry klipfisk in Norway is about six weeks, but it may take as much as two months. When the fish withstand pressure of the thumb in the thick part of the flesh they are judged to be sufficiently dried.

BRITISH METHOD OF CURING COD

The commercial curing of cod in Great Britain is conducted largely in Scotland, where the most important centers are Aberdeen and two groups of islands, the Shetlands and Orkneys. Some curing is done in Grimsby and Hull, the two most important fishing ports in England.

In Scotland the fish are usually landed fresh and split and cured on shore. In the deep sea fishery off Iceland and at Grimsby and Hull part of the catch is split and salted on board fishing vessels, with curing completed on shore.

Splitting, Washing, and Salting

The fish are headed and split much as in Newfoundland, Canada, and the United States, as is to be expected, since these fisheries were developed by fishermen from the British Isles. In Scotland, the backbone is usually cut through slantwise, over two joints of the vertebrae, as is done in Iceland. The backbone is cut off just below the anal opening. Mechanical equipment for heading and splitting the fish is in more general use than in North America.

The split fish are slid into a trough of fresh water. The blood is removed as completely as possible, black skin scraped away, and slime washed off. In larger plants, washing troughs are equipped with revolving stiff-bristle brushes, under a protective shield.

Shore-cured fish are usually salted in tanks or butts, the size and number depending on the scale of operation of the plant. According to Duthie (1911) a common size is 6 feet long by 4½ feet wide by 3 feet deep with a few tanks 8 feet long for curing large fish. The fish are laid in the tanks flesh side up, alternating heads and tails to obtain an evenly packed layer. Care is taken to lay the fish flat to avoid folds and wrinkles which would interfere with curing and mar the appearance of the cured fish. When butts or circular vats are used, the fish are laid in with tails to the center and napes to the side. Salt is scattered over each layer of fish. As in other cures, the amount of salt depends on size and thickness of the fish, type of salt, and weather conditions. The amount of salt varies from 17 to 20 pounds per 100 pounds of split fish, 18 pounds being a general average. According to Duthie (1911) 45 pounds of salt is a fair average for preparing a hundred weight (112 lb.) of dry-salted fish from 2¼ hundredweight of gutted fish.

Duthie considers this amount heavy salting but it would be regarded as a light cure in North America as cod are only left in salt from four to six days. The fish are scrubbed in brine as they are taken out of the tank to remove any undissolved salt or other debris. The cod can be dried immediately but if this is not feasible, they are piled into heaps called steeples, with a sprinkling of salt over each layer.

Duthie (1911) states that when fish are cured aboard vessels—for instance at the deep-sea fishing off Iceland—brine tanks are not available and the fish have to be dry salted. For this purpose "lockers" are fitted up in the sides of the vessels, and into these the fish are laid and salted in the same way as in tanks. More salt must be used in this case, however, and care taken to spread it liberally around the sides of the lockers, as well as over the fish, otherwise the exposed parts of the fish may be imperfectly cured. After lying for about a fortnight the fish should be turned over and re-salted.

Drying

The oldest method of drying cod is on rock beaches, as in Norway. It is still followed to some extent in Scotland, mostly in the Shetlands. The fish are first laid out to dry, skin side down, but are turned frequently during the first few days of drying. At night the cod are gathered into small heaps, known as "clamps," with the skin side up. They are covered with a canvas or tarpaulin for protection against night dampness. As drying goes on these heaps are gradually made larger in size. After about two weeks the fish are gathered up into large heaps, covered with a tarpaulin, and weighted down with stones laid on planks. This is said to improve the appearance of the fish and also to press out moisture. The fish are left for 10 to 14 days. This step is known as "sweating." At the end of the pressing or sweating period the fish are dried for about a week then piled and sweated again for about 5 days. After the second pressing the fish are dried for about 2 days, then stored. In good drying weather the entire drying period requires about 6 weeks. This is the same time reported for the Norwegian klipfish cure. Flake drying is also used. It does not differ greatly from the method followed in other localities. Some use is made of portable wooden and wire flakes.

Kiln Drying

One drying method widely used is a very simple type of artificial drier. It is known as "kiln" drying and its advantages are that it requires less time than the air-drying method, and is not dependent on weather conditions. Almost any warehouse that is dry, reasonably fireproof, and well ventilated may be used for kiln drying, although special buildings are sometimes constructed. Duthie (1911) gives the following specifications for a typical drying shed. It is 60 feet long by 20 feet wide with side walls 8 feet high. Six heavy posts run down the center of the building to support the series of joists which run across the building from side to side at the top of the side walls. Over these joists, about a foot above the top of the side walls, four strong beams are laid, spaced evenly and running from gable end to gable end. Pulleys are fastened to these long beams spaced about 12 inches apart. The "tenter frames" on which the fish are hung are suspended from these pulleys. Beams are fixed along each side of the building about 5 feet above the ground. Cleats for fastening the ropes connected with the pulleys are fastened to these beams. In the roof there are three pairs of hinged skylights arranged to open with pulleys and cords and in the walls below there are three pairs of windows. Cast-iron "hit-and-miss" ventilators, three on each side, are set in the side walls near the ground to regulate the draught. These four rows of oblong frames run down the building, the individual frame holding four rows of fish on each side. The fish, flesh side out, are fastened to hooks on the "tenter stick" and spaced about 5 inches apart, usually alternating heads and tails. When the frames are filled and hoisted, the lowest fish should be about 5 feet above the floor.

When the fish are taken out of the tanks or kenches where they have been salted, they are rinsed, then laid out to drain for a few hours before hanging on the frames. Drying is done with heat from portable coke grates having radiating iron plates covering the fire. Gas coke is used as fuel. The grates are filled and lighted outside, and the fire burns red before the grates are taken inside. This is to guard against discoloration by ash or smoke. The furnaces are set 12 to 15 feet apart and may be moved from time to time so that the fish will be dried evenly. When the fires are first brought in all the ventilators are open and the temperature regulated to about 60° F. Higher temperatures up to 80° F. are used when the fish are hard and in the final stage of drying (fig. 16).

The fish are given an average of 48 hours of continuous drying over these grates. They are then taken down and stacked in heaps or "steeples" to sweat for two weeks. They are hung up to dry again over the coke fires. If the cod are of medium size, a second period of 48 hours should complete the drying. Large fish are built up into steeples again, weighted down with stones and planks. After a third drying period of 24 hours they are usually sufficiently dried for the export market. Duthie (1911) states that:

> In the opinion of some experienced curers, the ideal cure can best be obtained by drying and sweating the fish

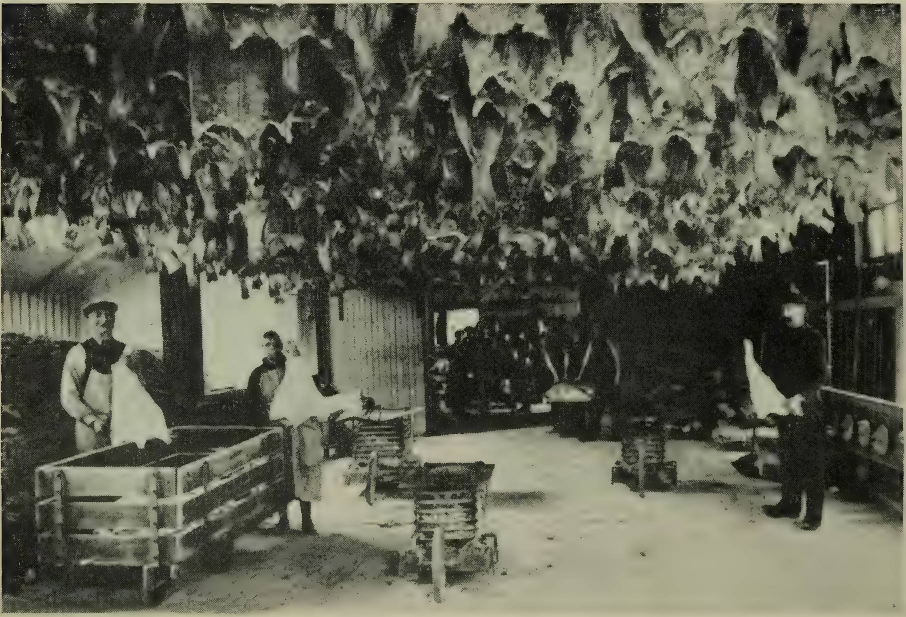

Figure 16.—Kiln drying salt cod in Scotland. (Copyright photograph courtesy Williamson and Co., Aberdeen, Scotland.)

outside until 24 hours "kiln" drying will make them as firm as desired. The sulphury taint of the coke fires . . . is scarcely discernible after only 24 hours in the drying shed, but it is claimed that even in this short time the fumes of the sulphur usually deter mites from attacking the fish afterward.

SPOILAGE IN DRY SALT COD AND OTHER CURED FISH

No comprehensive study has been made on types and causes of spoilage in the various dried and salted fishery products. Research has been made from time to time on special problems, mostly in relation to the codfish industry, as cod and related ground fish have traditionally been the most important species in the fish curing industry. Available information is therefore based mostly on dry salt cod. Many of the problems are common to all species of dry-salted fish though there may be differences in detail, a fact which should be kept in mind in reading this section.

BACTERIAL SPOILAGE

Reddening

The most important cause of spoilage is reddening. Outbreaks of reddening are much more troublesome in some seasons than others and perhaps more attention is paid to the problem than to other types of spoilage. Some curers believe that reddening is of more or less recent origin, but references from the eighteenth century indicate that this trouble was known then. Reddening can be a source of considerable expense and annoyance to codfish packers. It is less common on the Pacific than on the Atlantic coast. The comparative rarity on the Pacific coast is probably due to the cooler summer weather, and the use of a better grade of salt. Reddening is a type of spoilage characterized by the change to a pink or very unappetizing red color on the surface of fish. At first there is little change in odor and flavor, but both later make the fish unpalatable, as well as unattractive in appearance. This change may appear while the fish are being cured, when they are stacked in the warehouse, while they are being shipped, or after they have reached the market.

Reddening was one of the first problems to be investigated after the creation of the United States Fish Commission in 1871. It was also studied in Europe and Canada. The most valuable investigations contributing to a solution of the problem were made in 1911 by Bitting of the Bureau of Chemistry, U. S. Department of Agriculture; and in 1919 by Browne, an investigator of the U. S. Bureau of Fisheries. It was found that reddening is due to the growth of at least two organisms, the first a spirochaete causing a pale pink color, and the second a bacillus resulting in a deep crimson color. Apparently these forms grow in close harmony; hence all shades of color from pale pink to deep crimson are seen on salt fish. The Fisheries Research Board of Canada has devoted considerable attention to reddening in its studies on salt fish. Hess (1940, 1942) has obtained valuable data on the effect of environment upon the growth of red halophilic bacteria and on the effect of disinfectants and preservatives on these organisms. Gibbons (1935), Hampton (1938), Boury (1934), and others have also published studies on the subject. A review of the subject of reddening, with the more important citations of literature has been compiled by Tanner (1944).

Although there is confusion as to the nomenclature of the organisms involved in reddening, and it is believed that the same organisms have been given several different names, information is more definite as to the most favorable living conditions and possible methods of control. Growth of red halophilic organisms takes place in salt solutions containing between 5 and 15 percent of salt by weight. The temperatures necessary for growth range between 15° and 55° C. (59 and 131° F.). The range of salt tolerance can be increased in both directions from the optimum by gradual adaptation. The organisms grow well on heavily salted fish (unless dried to a low moisture content), brine, salt piles, and agar-containing fish stock saturated with salt. From the evidence at hand it is deduced that salt lagoons of the tropics are the probable source of most of the infections. Ordinary bacteria are usually destroyed after 10 minutes' exposure to bright sunlight, but sunlight does not kill the reddening organisms because of their pigmentation. They have been found to have great resistance to ultra-violet light. Evidence to date points to sea salt used in fish curing as the major cause of reddening. Solar salts from both Europe and America have been found to be infected; mineral salts are apparently free.

Prevention of Reddening

Bitting (1911) gives a number of rules for the prevention of reddening which have been found to work well in commercial practice. They are as follow:

1. Floors, weighing scales, wash tanks, dressing tables and everything with which the fish comes in contact in preparation should be frequently washed with water under strong pressure.
2. The water used on fish, or in any process around the plant, should be pure. Sea water from the vicinity of any town or dock should not be used since it is always polluted.
3. The butts, or hogsheads, and dressing tables, should be cleaned inside out and steamed, or washed with a detergent.
4. Drying should be carried on as far as possible; growth is inhibited on drier fish.
5. All refuse should be removed promptly, for bits of fish act as incubators in continuing infection.
6. Fish should be so kenched in the storeroom that free circulation of air is permitted around the stack. There should be no dead air spaces.
7. All equipment should be thoroughly washed and steamed each time after use.
8. The finished product should be held in a reasonably cool place and when shipped should be handled under proper temperature conditions, as are cured meat products.
9. All buildings should have good provisions for light. Most buildings are too dark.

Fumigation with the vapors of burning sulfur or sulfurous acid, or with formaldehyde, has also been found effective in controlling the growth of red halophilic organisms, using 10 ounces (283 gm.) of formaldehyde or 5 pounds of sulfur per 1,000 cubic feet (28.3 cu. m.) of space. Fish-curing salt mixtures containing 2 percent sodium acid phosphate and 0.25 sodium benzoate have been found to stop the growth of red bacteria. Boric acid mixed with fine salt and dusted on dry salted codfish has been used commercially for about 50 years. It has some effect on inhibiting the growth of red bacteria on dry salt fish. The use of these two chemical preservative agents is permitted under the Food, Drug and Cosmetic Act only if the amount is less than ⅒ of 1 percent, and if their presence is declared on the package together with directions for removal.

Dun Cod

"Dun" cod is another form of bacterial discoloration on dry salt fish. It is a type of spoilage that has also been known for a long time. This is dry salt fish on which dry, freckle-like spots have formed. These spots may be found either on the skin or flesh side and usually on fish that have been cured for some time, but may be found on comparatively fresh fish. The degree of infection varies from a scattering of chocolate brown spots to an almost complete coating of the surface (Hess 1940). The standard commercial method of control has been to scrub the fish with a brush under water, wipe off, powder the surface with a mixture of fine salt and boric acid, and dry for a day or two. Dun fish has been found to be caused by a brown halophilic mold (*Torula epizoom*). This organism has an optimum of 10 to 15 percent salt with growth over a wide pH range. Recent investigators have found that sodium propionate is an effective inhibiting agent and is suitable for commercial use (Frank and Hess 1941). Fumigation with formaldehyde or burning sulfur has also been recommended. According to Stevenson (1899), dun fish was at one time prepared as a type of cure for markets which desired its special flavor.

Molds

Dry-salted and smoked fish are sometimes attacked by mold, particularly where the fish have been very lightly salted with most of the moisture removed by drying. Some of the molds have been identified as: *Rhizopus nigricans*, the black mold of bread, associated with the spoilage of many varieties of food; *Aspergillus glaucus*, a green mold found on hay, grain, preserves, jellies, and dried meats, and one of the most important common molds; *Mucos mucedo*, at first yellow, then becoming dark brown or black; *Botrytes grisea*, which produces a white color; and *Thomnidium* sp., which is characterized by an orange-yellow color. The presence of molds indicates poor storage, that is, the product has been allowed to become damp and held at too high a temperature. When these molds first appear, a commercial method of control is to rub the surface well with a vinegar-dampened cloth and then dry the fish for a few hours.

OTHER TYPES OF SPOILAGE

Dry-salted fish, if properly prepared and stored, are generally immune to the common spoilage organisms attacking fresh fish. The fish are subject to spoilage through a variety of other causes from the moment the curing process begins. These agencies may be divided into: animal life, insects, enzymic changes, and physical and chemical deterioration.

Animal Life

The most common types of destruction through animal life are by sea birds such as gulls, while the fish are being dried, and by rats or mice while the cured product is in storage. Sea gulls tear the fish while they are on the drying racks and scatter their droppings over the surface of the drying fish. In many areas the drying racks are given special protection, such as a covering of old fish netting.

Among mammals, the rat has been called "the arch enemy of the food preservationist" and different species of mice may also be included (Rector 1925). It is said that these rodents eat half a billion dollars worth of food annually in the United States, including dry salted fish, and in addition they destroy a great deal more. This topic is discussed at length in publications on food preservation, and agencies such as the U. S. Department of Agriculture and the Branch of Predator and Rodent Control of the U. S. Fish and Wildlife Service have made extensive studies with recommendations for control measures. Control can be summarized in a few words: Good warehousing and packing is probably the best single means of reducing spoilage by rats and mice.

Insects

Two types of insects in particular damage dry-salted and smoked fish. Freshly salted fish on drying racks are attacked by several species of flies, which lay eggs that soon hatch into maggots. Infestation with maggots is entirely unnecessary. It is most apt to occur where the fish are slack (light salted), not carefully dried, and where no attention is paid to the sanitary condition of the plant or drying yard. If the flakes (drying racks) are properly located and the yards kept clean, there is very little danger of maggot infestation. Flies that may appear in still, calm weather will be kept from doing damage by a smudge made from green wood.

The most common of European insect parasites, present to some extent in America, is the fish mite. This is apt to appear if the drying fish becomes the least damp. If codfish are "mited" they look as if they had been sprinkled with coarse black pepper. Mites may attack fish either while on the flakes during the drying process, or when stacked in the storeroom when drying is completed. Mites commonly appear when a sudden fog comes up while the fish are laid out to dry and the curers cannot get them gathered up before they are damp. The drier the fish are at such a time, the greater is the risk. Drying the damp fish in a shed over a low clear fire for 24 hours should give sufficient protection. Some curers take the additional precaution of scrubbing fish in strong brine before they are placed outside for a final drying. To guard against infestation by mites while the dried fish are in the storeroom, the warehouse should be kept thoroughly clean, dry, and airy. The salted fish should not be stacked in the warehouse during the heat of the day. They should be gathered from the flakes either in early morning or at evening when the heat of the day is past. If the climate is damp, the dried fish should be well covered in the warehouse.

Enzymic Changes

Enzymic changes are usually thought of as occurring in fresh fish. Recent studies indicate that these changes may take place in preserved fish in storage. They are not found in canned foods but enzymic deterioration has been found to take place in frozen fish stored at 0° F. Enzymic changes may also take place in dry-salted fish.

Enzymes are digestive agents which break down or build up food substances. Enzymes are organic substances and to date little is known as to their exact composition. The digestive fluids of fish are very rich in enzymes. The cells in fish tissues also contain enzymes which do not cease their activity upon the death of the fish, but may digest the cells in which they are contained. This process is inhibited or greatly reduced by dehydration but it may still go on, though at a much slower rate, if other conditions, such as temperature, are favorable. For example, dehydrated fish with a good flavor, stored in a sealed metallic container, may show undesirable changes in both color and flavor after several months of storage at room temperature, or about 70° F.

About all that can be done to reduce enzymic deterioration in dry-salted or smoked fish is to dry the fish down to a low moisture content, and store them in a cool place, at an even temperature, if they are to be held for any length of time. Enzymic spoilage is comparatively easy to control in smoked, dried, and salted fish. It causes the most trouble in the preparation of dehydrated fish.

PHYSICAL AND CHEMICAL DETERIORATION

The principal physical and chemical causes of spoilage of dry-salt cod, which are also more or less important in other cured fish are: (1) oxidation; (2) light; (3) temperature changes; (4) water; (5) fire; and (6) contamination with foreign materials. This is a fairly complete outline of types of deterioration caused by physical or chemical action causing harmful changes that have been studied by chemists, engineers, and food technologists.

Oxidation

Oxidation is probably the most important chemical change which may take place in dry-salt cod and other cured fishery products. It may occur while the fish are being cured, or while they are in storage awaiting retail sale. It is discussed at some length in other sections of this report as it affects the preparation of specific products. The "sun burn" of dry salt cod, and the "rusting" of salt herring, alewives, and mackerel are instances of oxidation. Its importance may be illustrated by saying that it is sometimes necessary to discard 25 percent of mackerel that are being repacked because of oxidative changes. Sometimes an entire lot of dry-salt cod is lost on the flakes because of oxidation due to faulty drying. Oxidation occurs most rapidly and frequently in fatty fish but may occur in "lean" fish such as cod. It is characterized by the development of rancid flavors and odors, and the occurrence of undesirable color changes. Study of oxidation changes in cured fish is handicapped by the fact that these alterations are often complicated by deterioration caused by micro-organisms, enzymes, and probably other factors strictly chemical in action.

Light

Sunlight is not usually considered a destructive agency; on the contrary, it is thought of as beneficial. Yet it may set in motion many chemical reactions that assist in the spoilage of cured fishery products. As a matter of fact light waves, particularly the short invisible rays called ultraviolet, are intensely active and very few organic substances can stand long exposure to intense light without some changes in composition (Rector 1925). That is the principal reason for the caution printed on labels, "Store in a cool, dark place." Light changes occur in salted cod when they are first set out to dry. Intensity of light rays is a factor. For this reason it was formerly considered impossible to obtain dried salted fish of good quality in warm climates. The effect of light is discussed in detail in the section of this report, Dry Salting Fish in Warm Climates. Light changes also occur when cured fishery products are packed in glass containers. Shredded cod packed in glass tumblers gradually turns yellow and rancid on long exposure to light. Spoilage in which light is a causative agent usually develops at such a slow rate as to be almost unnoticeable. For this reason many of the changes in which it is a factor are obscure. Light is probably not important as a direct and single cause of damage, but is so often connected with some obscure cause of spoilage that it must be carefully considered.

Temperature Changes

Temperature of storage is an important factor in all types of spoilage described so far in this discussion. The development of insect infestation, micro-organisms and enzymes, is greatly affected by temperature. True chemical changes of all kinds increase in intensity as the temperature rises. It has been calculated that the speed of reaction is doubled with each increase of 18° F. Temperature is, however, a contributory cause rather than a principal agent in these changes. There is, in addition, spoilage due directly to marked temperature changes. This may be of two types;

first, changes caused by excessively low temperatures and second, those due to temperatures higher than normal.

Cured fishery products are not damaged by freezing. In fact freezing temperatures preserve dry-salt cod and other cured fishery products for much longer periods than would otherwise be possible. Some types of smoked fish, such as kippered herring, deteriorate after a comparatively short period of freezing storage, but in these instances freezing is a contributory influence, not the principal direct cause.

In most spoilage initiated at high temperature, temperature itself plays only an indirect part. In general the activities of insects, microorganisms and enzymes are intensified by temperatures higher than normal. As to direct damage, there is some evidence of loss of flavor and physical softening not due to decomposition, caused by high temperature. Oxidation, colloidal changes, and the action of light are all speeded up by a rise in temperature. When cured fishery products are to be held for long periods, the knowledge that the speed of chemical reactions is reduced one-half for each 18° F. drop in temperature immediately suggests storage at low temperature. In the storage of hard-salted cod, it has been determined that storage at 40 to 45° F. is optimum.

Water

In methods for the preparation of dry salt cod and other cured products it has been emphasized that removal of the natural moisture of flesh is the principal requirement in preservation. The presence of natural moisture accelerates spoilage. The food technologist also has to deal with extraneous moisture which may come in contact with cured fishery products and also act as a spoilage agent.

Extraneous water usually gets into dry salt fish in one of the following ways: rain on the fish while exposed on drying racks; wetting with salt or fresh water during transportation by ship; and wetting due to defective plumbing in the storage building or as a result of attempts to put out a fire. Fire and smoke damage will be a complicating factor in spoilage in the last instance. Water damage may also be caused by a third factor, that of atmospheric humidity. If cured fish are not given good storage when in a damp, humid climate, or if attempts are made to dry salt fish in such a climate without special precautions, the excess moisture in the atmosphere is absorbed by the product.

No matter how the water gets into the dry salt fish or other cured fishery product, the result is the same; they will mold or become slimy. In warm climates "reddening" is increased (or intensified) by high water content. If water damage is extensive the growth of spoilage bacteria is accelerated.

Fire

Fire damage may occur in any one of several forms. The cured fish may be entirely consumed or become so charred and carbonized that it is unappetizing and inedible. It may absorb such products of combustion as smoke, dust, or cinders, destroying all or part of its value. Fire protection is valuable as a spoilage preventive agent at all stages of preparation and distribution. Rector (1925) states that:

> Animal foods of all kinds on account of their high protein content give off very disagreeable odors when burning. They are also as a class very susceptible to odors from a distance and are likely to become damaged by comparatively little exposure to smoke.

Contamination With Foreign Materials

There are many opportunities for the contamination of cured fish by foreign substances. It is most apt to occur during shipment, storage, or at the retail store, for while the fish are at the plant the packer is able to control conditions. The principal types of contamination are substances such as kerosene, lubricating oil, or other petroleum products, which may come in contact with the dry salt fish during storage or shipment; poisonous chemicals; air-floated dust; metallic contamination, especially by zinc, tin, or copper; contamination by coal and decomposing organic matter which may occur during storage or shipment. Good packaging by the packer is therefore essential. Prevention of spoilage by contamination through foreign agents may be given in two words, improved packaging. A slight additional cost will prevent the loss of entire lots of fish.

Dried salted fish may act as a contaminating agent to other food products. If the fish are exposed in the open, especially when not skillfully prepared, and have a fairly high moisture content, the strong "fishy" odor is absorbed by other foods. For this reason some grocers are unwilling to handle dry salt cod or other cured fish. The retail sale of cured fish has naturally suffered. This is an additional reason for better packaging.

MISCELLANEOUS DRY SALT FISH

ANCHOVIES, SPANISH STYLE

The curing of anchovies centers around the Mediterranean and South Atlantic. Spain, Italy, Portugal, France, and Greece are the most important producing areas. Several species of anchovy are found in the Americas. The Pacific anchovy (*Engraulis mordax*) found from Vancouver Island to Lower California, is the largest and most valuable species in the Americas. It is a good example of our under-utilized fish species. The California anchovy is known to frequent the coast in large numbers, yet it is used commercially in only small amounts. From Puget Sound and Willapa Harbor southward, the anchovies are caught commercially at irregular intervals, but mainly during the summer months. The catch is taken largely by small purse seines, lampara, and ring nets. The fish are used mostly as bait, either alive or salted. Some are kippered or cured Spanish style, which is the usual way this species is prepared for human consumption. Anchovies salted for bait are given much the same cure as dry salt herring.

The preparation of Spanish style anchovies is carried on mostly at Monterey, although occasionally small lots are packed at San Pedro. The freshly caught fish are first gutted and headed. The workmen do this by pulling the heads off with their fingers. The anchovies are dropped into three-quarter or half-ground salt in which they are thoroughly mixed, then packed in salting tanks or large butts. Accurate data are lacking as to the amount of salt but it is reported that it is from 25 to 30 pounds per 100 pounds of fish.

In order to obtain the proper cure, the fish must be exposed to warm temperatures. Therefore, the tanks are held at temperatures varying between 80° and 90° F. for a period of about 4 months. They are ready for use when the flesh has a red color from skin to backbone, and a strong, sharp flavor. The anchovies are removed from the tanks and drained for several hours, then packed in round tins holding 8, 14, or 28 pounds. The fish are pressed to remove excess moisture and oil. When the proper net weight has been filled in, the cans are sealed, and are then ready for shipment. The cans are not processed or pasteurized, and preservative agents are not used.

BARRACUDA

The Pacific barracuda (*Sphyraena argentea*) is dry salted commercially only in southern California. At one time it was a regular item of some importance, but now it is cured only when there is a surplus of barracuda on the fresh-fish market. In some years no production is recorded. There is usually some small noncommercial production by the fishermen for their own use. There is also some dry salting of barracuda in Puerto Rico and Florida for home consumption. When properly cured, the barracuda makes a very good dry salt fish, white and dry, and of excellent flavor; however, some of the product is dark in color and has a strong flavor, probably due to faulty methods of curing.

The recommended method for curing barracuda is as follows: The head is removed, leaving the collar bones. A slit is made down the middle of the belly to the vent, and the body is cleaned thoroughly. A cut is made just above the backbone on the abdominal side, cutting along a line where the ribs join the backbone, and continuing almost to the tail. A similar cut is made just below the backbone. A sweep of the knife through the thin section of rib bones still adhering to the flesh removes the backbone, which is broken off near the tail. These cuts must not reach through to the skin. When split the barracuda should lie flat in a single piece. After splitting, the fish are washed thoroughly in salt brine and soaked 30 minutes to remove all traces of blood. The flesh is scored almost to the skin, the cuts running longitudinally from collar bone to tail at approximately two-inch intervals.

The fish are allowed to drain, then roused (dredged) in a shallow box of packers fine or three-quarter ground salt. The fish are picked up with as much salt as will cling to them and packed flesh side up in tanks or tubs. Sufficient salt to cover any exposed surface is scattered over each layer of fish. As a general rule, approximately one part of salt should be used to four parts of fish. A loosely fitting cover is placed on top, with sufficient weights to keep all fish under the surface after the brine has formed.

After 48 hours in salt the barracuda are removed, scrubbed well in salt water or brine to remove any slime or excess salt, piled into heaps to drain for 20 or 30 minutes; then laid on racks to dry. The racks are usually wooden frames with legs 3 feet high and a top of reed, bamboo, or galvanized chicken wire. If drying is carried on under the direct rays of the sun, oxidation or rusting sets in immediately. However, if the barracuda are kept shaded, in a breezy location, they will dry well, with a clear color, and will not oxidize readily afterward. The fish must be turned frequently during the first day of drying. At the end of the day the fish are stored under cover in a dry shed. They are weighted to press out additional moisture. The next morning the fish are again laid out to dry. After five days of good drying weather the barracuda are usually sufficiently dry. If poor drying weather sets in, the barracuda are restacked in the storage shed and weighted very heavily.

HERRING

Before World War II, the largest production of dry-salted herring was in British Columbia, where large amounts were prepared for export to the Orient, especially China. Production in British Columbia has decreased to a small fraction of the former level. It is not known whether postwar conditions will call for a large-scale manufacture of this article. Dry salt herring has never been of more than minor commercial importance in the United States. The production of dry salt herring in this country has varied between 150,000 and 200,000 pounds annually.

As packed on the Pacific coast, dry-salted herring is a very roughly prepared product. The Pacific herring (*Clupea pallasii*) are not gutted, scaled, or washed. As the fish are landed, they are shoveled into a heap of salt, turning the pile over with a large scoop shovel until herring and salt are thoroughly blended. The mixture is then packed in large tanks with a capacity of 100 barrels or more. Additional salt may be added to the tanks. The herring are allowed to cure for several days, forming their own brine. They should be left in salt for 10 days, but if time is short, they can be removed in from 3 to 7 days. They may be left in salt up to two or three weeks.

When the packer is ready to make a shipment, the herring are shoveled out of the tanks onto the floor in heaps which are covered with the excess salt from the tanks. The fish are allowed to drain for 1 or 2 days. They are then shoveled into large wooden boxes similar to those used in shipping fresh halibut or salmon. Some salt is added between the shovelfuls, the amount depending on the length of time the herring have been in the salting tanks. A scattering of salt is spread over the top of the fish, the cover is nailed on the box, and it is ready for shipment. Dry salt herring is reported to be valued in the Orient largely for its salt content, being used for seasoning of food such as stews.

MACKEREL

In Spain, southern France, and on the coast of North Africa, especially Algeria, small mackerel are cured according to the same method used for anchovies. Fish of a size from 15 to 20 to the kilogram (2.2 pounds) are used; that is, mackerel averaging about 8 to the pound. On arrival at the plant, and before heading, the mackerel are placed in tanks without brine, the bottom of the tanks sprinkled with salt. The baskets or boxes of fish are thrown into the tank by hand to form thin regular layers. Handfuls of salt are thrown over and among the layers of fish, so that each layer has a thin covering of salt.

Brine begins to form through extraction of moisture from the fish by the salt. In about half an hour a saturated brine is formed in which the fish are almost floating. The fish are washed in this brine carefully, one at a time. As they are washed they are placed in small baskets for drainage, and then spread on tables for heading and eviscerating.

When the mackerel are dressed they are replaced in the baskets which hold 8 to 10 kilograms (17.6 to 22.0 lb.) each. Filled baskets are emptied into a washing tank which is one-third full of fresh 25° B (100° salinometer) brine. Some salt is scattered through the fish as they are thrown in.

As in preparing anchovies, it is desirable to have several tanks full of fish before beginning packing so that this operation will not have to be interrupted. The first step is to wash the mackerel thoroughly, after which they are placed in baskets to drain before being placed in the barrel.

Enough "demi-fine" No. 2 fish salt (three-quarter ground) is scattered on the bottom of the barrel to cover the wood. The tiers are not in rosettes or transverse layers as is the custom in packing anchovies and sardines, but each is a series of straight parallel rows, with each row containing one, two, or three fish according to its place in the layer.

A single fish is laid on its side, the back against the wall of the barrel. Two fish are then packed in with backs against the belly of the first fish, heads against the sides of the barrel, and tails crossed. This is continued until the last row in the layer is reached. The single fish in this row is packed belly to belly against the preceding fish in the next row with its back against the staves of the barrel. The gaps left where the tails of the fish are crossed are filled by fish laid alternately with the heads to opposite sides. The tails are hidden under preceding fish in such fashion as not to be apparent. A very thin layer of salt is then thrown over the fish, and the packer is ready for the next layer. It is important to use careful packing, keeping the layers even and the fish straight in the rows.

When the barrel is filled to the rim, four or five additional layers are packed above the top. The last layer is given a slightly heavier coating of salt, the lid is placed on top and loaded down with weights to an amount of 40 or 50 kilograms (88–110 lb.). This is called the "first filling." The next day the brine which has formed is drained off and discarded, and the top layer is washed until the fish are bright and clean. The barrel is then filled with mackerel of the same lot. This is the second filling. Three days after the second filling the process is repeated for the third filling.

Two days after the third filling the brine which has collected is again drained off, the top layer is washed and covered with a layer of quarter-ground salt to a uniform depth of ½ centimeter (⅜-inch), the cover is placed on top, and the barrel is set on a rack in the fish house to cure. Some fresh brine is poured into each barrel to make up for the brine which was drained off. The barrels must be inspected for leaks from time to time while they are undergoing the curing process.

The ripening is finished in from 2 to 3 months. It is much more rapid than that of the anchovy and the sardine by reason of the much greater quantity of blood contained in the mackerel. When the fish are well matured, the flesh is a beautiful red, similar to that of the bonito, and liberates the characteristic agreeable anchovy odor. They are eaten as an hors d'oeuvre (Dieuzeide and Novella 1942).

MULLET

The striped mullet (*Mugil cephalus*) is the most important dry salted fish in the South Atlantic and Gulf of Mexico areas. The principal area of production is from Carabelle to Cedar Key on the Gulf coast of Florida, with most of the production at these two ports, and in a few other scattered localities.

Most of the mullet are taken by run-around gill nets with a smaller quantity caught by haul seines. A great deal of the mullet must be transported a considerable distance to the curing plant. Some are still brought in by boat but probably the greater share is now carried by truck. No special care is used in handling. As a rule the fish are dumped in the body of a truck, without ice. When delivered, they are frequently mixed with sand and weed. The fish should be washed before loading in the boat or truck and given better care in handling.

Preparation begins as soon as the mullet are unloaded at the fish house. They are first washed to remove sand and other debris. The heads are usually removed, especially from the larger fish, but the collar bones or napes are retained, since if this is not done, the fish are apt to shred in subsequent handling. The mullet are split in a manner usually referred to as mackerel style. The splitter holds the fish in place on the splitting board with his left hand, with its tail toward his body. He places his knife blade so that it will scrape along the backbone, then splits the fish along the back from head to tail without cutting through the belly, leaving the backbone on the right side. The cut is not completed, and two halves are left attached at the tail of the fish. The backbone may be partially removed in the larger mullet by making an additional cut on the underside of the vent, thus cutting the backbone loose so that it can be broken off for about three-quarters of its length.

If the mullet contain roe, the sacs are carefully removed for salting separately. The viscera, coagulated blood, and membrane, or so-called black skin lining the body cavity are scraped out as thoroughly as possible. The more careful salters scrub the intestinal cavity with a piece of gunny sacking or coarse canvas, the most effective means of removing black skin and blood. The flesh is scored longitudinally on both sides at intervals of about one inch, so that the salt may readily penetrate the flesh (Jarvis 1945c).

The fish are then thrown into a tub of clean sea water, where they remain for about 30 minutes, after which they are thoroughly washed. This soaking also aids in removing diffused blood from the flesh. After the mullet are removed from the washing tank they are allowed to drain for a short time to remove surplus moisture. The fish are then rubbed thoroughly with a medium-grain salt, usually a Louisiana mined salt. They are next piled in kenches or stacks inside the fish house. The kenches are about 3 feet high. The fish are arranged in regular layers, skin side down and two deep, with heads to the outside and tails to the center. A thin layer of salt is scattered over each layer of fish. The total amount of salt used is about 30 pounds to 100 pounds of fish.

The mullet remain in the kench until they are to be placed on the market, which may not be for three or four months. Some packers weight down the kench to press out more moisture, and may re-kench the fish once or twice, reversing the order of layers, but this practice is not common. For shipment, the fish are brushed, and weighed, then placed in open boxes or bushel baskets with a scattering of salt on top.

The following method is used by those who wish to prepare a really choice product and are willing to go to the extra trouble. The cleaned fish are washed thoroughly, and dropped into a tub of salt brine made in the proportion of one pound of salt to one gallon of water. They are allowed to soak in the brine for 30 minutes to remove all traces of blood from the cut flesh. After brining, the mullet are drained for at least 20 minutes to remove surplus moisture.

A shallow box, about 2 feet square, is filled with salt, usually a dairy-fine grade. The drained fish are rolled in the salt, which is also rubbed into slashes in the flesh. A thin layer of salt is scattered over the bottom of a tub or salting tank. The mullet are then picked up with as much salt as will cling to the body and are packed in even layers in the tub, flesh side up with each layer at right angles to the preceding one. A small amount of salt is scattered between layers. A loose-fitting cover is placed on top which is weighted down enough to cover the mullet by brine formed. In warm weather, a saturated brine may be added immediately, instead of allowing the brine to form gradually by extracting moisture from the flesh. The amount of salt used averages 25 pounds to 100 pounds of fish. This is about 17 percent less than that given previously for kench curing mullet.

The mullet should be sufficiently salted in about 48 hours, after which they are removed from the brine. The fish are then scrubbed thoroughly to remove any traces of excess salt and placed in layers, flesh side up (except for the top layer) on a low rack. The stack is weighted down heavily to press moisture out of the fish. The next morning the mullet may be hung in a shady spot where there is a good breeze, or dried on racks of chicken wire in an open-walled shed. At night they are re-stacked and weighted down, but are set out to dry again the next morning.

In good drying weather the mullet will be sufficiently cured after 6 days of drying. In unfavorable weather, and for larger fish, more time is required. In damp, humid weather the salters allow the fish to remain kenched, restacking them occasionally with a scattering of salt between the layers. After the drying process is complete, each fish is sprinkled with fine, dry table salt, wrapped in waxed paper, and packed in lightly covered wooden boxes holding about 10 pounds.

KINGFISH (KING MACKEREL)

Small quantities of king fish, also called king mackerel (*Scomberomorus cavalla*) are dry-salted in the Florida keys and on the west coast, for local sale. The quantity so prepared has decreased in recent years, but this is still a commercial product.

The fish to be salted are usually those taken during the first part of a long fishing trip, or those which cannot be disposed of profitably in the fresh-fish market. The fish are split open and eviscerated. As a rule the backbone is cut out. The membranes and blood are removed and the fish washed indifferently. The thick flesh is slashed crosswise from back to belly, with cuts about 2 inches apart. A small amount of salt is sprinkled over the surface of the flesh and rubbed well into the cuts. If the fish are to be used in a day or two, they are given no air drying, but if held for a longer period they must be dried. The fish are spread on shed roofs or woodpiles, flesh side up, or are hung under the eaves by their tails. If they are not hung, the kingfish must be turned frequently during the drying period. The amount of drying given depends on the individual curer.

RED DRUM (CHANNEL BASS)

The red drum or channel bass (*Sciaenops ocellata*), is caught in considerable numbers along the South Atlantic coast in the late summer and fall. The greater part of the catch is made with run-around gill nets and handlines, in almost equal amounts. A lesser quantity is taken by haul seine and a few by trolling. As there is not a great demand for this fish in the fresh-fish market, some of the catch is dry-salted for local use, especially along the North Carolina banks. The only market is among the coast people, the fishermen, and their neighbors on the shore of the adjacent mainland.

The heads are chopped off with a hatchet, the fish are split into two sides, and the backbones are removed. Each side is scored through the flesh lengthwise from collar to tail, the cuts penetrating almost to the skin, and about two inches apart. The sides are washed thoroughly in sea water or brine, to remove all traces of blood or other waste, and are drained for about 20 minutes.

The drained sides are rolled in a box of fine salt, which is rubbed well into the flesh, especially into the cuts. The sides are then packed in tubs, flesh side up, in even layers. A little more salt is scattered over each layer and the top is weighted down. The tub is then filled with a saturated brine. The fish are allowed to remain in brine for about two weeks. The sides are then removed and scrubbed thoroughly to rid them of any excess salt, blood spots, or black skin. The sides are stacked not more than 2 feet high, the bottom layer being placed skin side down, and the others skin side up. The top is covered by boards and weighted down with rocks.

The next day the sides are hung in a shady place for about 10 hours of air drying. If the weather is unfavorable, the kench is re-piled, reversing the order of layers. The flesh must not be exposed to direct sunlight during the first few days of drying, or a crust will form which hinders the removal of moisture from the inner flesh. Oxidation is also more likely to occur. At the end of the day the fish are stacked as before and weighted down more heavily. They are left in the kench during the next day, then given a day of drying, followed by a day of pressing. This is continued, increasing the weights each time the fish is pressed, until the fish are well dried. The product is considered thoroughly cured when the pressure of a thumb in the thick part of the back leaves no impression.

SALACHINI (SALACHI)

This fishery product is specially favored by the Italian and Greek trade. Large amounts are prepared in the Mediterranean area where the product is believed to have originated. It is also packed in California in the Monterey Bay area. Occasional packs are sometimes prepared in the Los Angeles harbor area. The English name is dried salted pressed pilchards.

Only the pilchard (*Sardinops caerulea*) may be used in preparing salachini. There is no selection of raw material, in that all sizes are used, but the fish must be fresh and firm.

The pilchards are salted in the round in tanks, using California half-ground fishery salt, which is mixed with the fish. Additional salt is scattered on top and the brine is allowed to form from the fish. The proportions of fish and salt have never been determined accurately, but it is estimated that 35 pounds of salt is used to 100 pounds of fish. The pilchards are left in salt for at least three weeks, sometimes longer. When they are to be prepared for shipment they are removed from the tanks and allowed to drain. If there is any excess salt on the fish it is removed by washing in brine.

When the pilchards are sufficiently drained they are packed in small tubs, 18 inches in diameter by 12 inches high. They are not gutted, gibbed, or headed. The fish are packed in the tubs rosette style, with heads to the outside and tails to the center. About 6 additional fish are required to fill the center. Approximately one thousand fish, 7 to 8 inches long, are packed in a tub. A collar of tin is fixed around the top so that the fish can be packed above the level of the tub top. When fish have been packed in to the level of the collar top, a cover slightly smaller than the tub top is set in place, and the fish are subjected to heavy pressure. This is usually done by setting the tub under an overhead beam, then fixing a jackscrew in place, and turning the screw. After the sardines have been pressed down, the tub must be refilled once or twice. Two hundred pounds of salted fish are reduced to approximately 75 pounds of finished product by this method. The tub is not yet tightly coopered so that the brine and a good deal of oil may run out of the bottom and between the staves. The oil is collected and sold.

Salachini is also packed in boxes and in tubs of other sizes. It is characterized by the more or less red-colored flesh and rather sharp, pungent flavor.

The method given for preparing Salachini is similar to that used for many years in Cornwall for preparing pilchards for the Italian market under the name "fumadoes." It is described by Holdsworth (1877) as follows:

> The curing is the especial work of the women, who pack the pilchards in alternate layers of coarse salt and fish on the stone floor of the curing house until the "bulk" has reached a height of 5 or 6 feet. Here the fish remain for a month, and the oil and brine draining from them are carried off by gutters in the floor to a cistern. When the fish have been sufficiently salted, they are washed and packed in hogsheads, each layer of fish being placed with their heads outward and with a "rose" of fish in the center. A circular piece of wood called a buckler and rather smaller than the head of the cask, is then placed on the top of the fish and strong but gradual pressure is applied by means of a lever until the mass of fish is reduced one-third in bulk and a great quantity of oil squeezed from them.
>
> This drains through the sides and bot-

tom of the cask, the hoops of which are not at that time very tightly driven, and is collected as before. The quantity of oil obtained from the pilchards depends on the season, but at least 2 gallons of oil are expected from each hogshead . . . The cask is filled up three times before the pressing is finished, which is not until after 8 or 9 days, and then the hogshead (50 gallons) of fish should weigh 4 cwt. gross. The average number of fish packed in a hogshead is about 2,500.

As the name of this product indicates, the fish were originally smoked. Now salting and pressing alone are used for curing purposes. The salted fish are said to keep longer and have a better flavor than the smoked pilchards.

SALMON

Before World War II large quantities of salmon were dry-salted every year on the Pacific coast, mostly for export to the Orient. With the restoration of normal trade conditions, it is hoped that this trade can be resumed. The greater portion of the pack has been prepared in British Columbia. Little interest in this method of curing salmon has been shown in the United States for a number of years, but occasionally when chum salmon are in little demand for canning purposes, considerable quantities are available for dry salting at a price which should show a profit. Statistics for 1940, the last prewar year when conditions approached normal, give the United States production of dry-salted salmon as 29,000 pounds.

Chum (dog) salmon (*Oncorhynchus keta*) is used largely in the preparation of dry-salted salmon though other species are sometimes used. In Siberia, where an increasing amount of dry-salted salmon was put up every year before the outbreak of World War II, red (*O. nerka*) and coho (*O. kisutch*) salmon were used to some extent. Many of the fish are taken by gill net, though salmon caught by other gear may be used, especially when the market is glutted.

In preparing dry-salted salmon, the fish are headed leaving the collar, split down the belly, and eviscerated. The blood is scraped out as thoroughly as possible and if large, the fish are split into sides. The backbone may or may not be removed, depending on the custom of the individual curer. As a rule, it is removed when the salmon are split into sides. Small fish may be split almost through to the skin, but are left in one piece and the backbone is not removed. The dressing and splitting process is the same as that described for hard-salt or pickled salmon but is carried out more roughly after splitting. The fish are washed and given a final cleaning in the washing tank to remove bits of viscera or other offal overlooked previously.

When the salmon are well drained after washing, they are laid down in stacks with a layer of salt between each layer of fish. The salt must be thick enough to cover the surface of the salmon layer completely. All layers are piled flesh side up, with the exception of the top one, which is placed skin side up for the purpose of better protecting the fish against dirt or other contamination. Sometimes the fish are cured in vats or tanks as in pickling salmon. The brine is formed naturally and the amount of salt required is somewhat smaller than normally used in curing fish. If salted in tubs or vats the salmon are arranged as neatly as possible, flesh side up, alternating heads and tails, with the thick edge of the side toward the side of the tub, small pieces being packed in the center to make the layer even. If cured in stacks or kenches the salmon are laid down in rows, alternating heads and tails. The amount of salt required in dry-salting salmon is approximately 35 to 40 pounds per 100 pounds of fish, for the kench cure; 25 to 30 pounds for the tank cure (Jarvis 1936b).

When the salt has struck through, that is, when the fish appear thoroughly cured and it is determined that the salt has penetrated completely, they are ready for packing. An average of two weeks in salt is required. If the curer is not ready to make a shipment the fish may be left in salt longer.

Dry-salted salmon are packed in large wooden boxes holding 400 to 500 pounds, with salt scattered between each layer of fish. No particular system is followed in packing except that the packers try to make the layers even, without large air spaces. From 10 to 15 pounds of salt per 100 pounds of fish will be used in repacking. The product receives no further processing but if it is to be held any length of time before shipping, the boxes should be again repacked. Dry-salt salmon is reported to be valued for its salt content in China where there is a high tax on salt. It is sometimes added in small pieces to soups and stews for this reason, but a great quantity is eaten raw as a relish. Dry-salted salmon have been a favorite New Year's gift in Japan.

DRY SALT ATLANTIC SALMON

Some Atlantic salmon (*Salmo salar*) is dry salted in Canada and Newfoundland by a method resembling the Scotch and Norwegian cures for kippering salmon as described by Duthie (1911). The method was probably introduced from Scotland.

The fresh salmon are chilled in ice until the flesh is firm. The fish are headed leaving the collarbone. Smaller salmon are split down the back to lay flat in one piece, and from three- to four-fifths of the backbone is removed. Large fish are split into sides, removing the entire backbone. The viscera, all traces of blood, membranes, or other offal are removed and the fish are washed thoroughly, then left to drain.

A curing mixture is made up in the following proportions which is sufficient for about 10 pounds of fish: 2 pounds of packers fine salt; 1 pound of brown sugar; 1 ounce of saltpeter; ½ ounce whole black peppers; ½ ounce whole cloves; and ¼ ounce bay leaves. The spices are crushed and mixed well with the other ingredients. The mixture is rubbed into the flesh of the salmon, placed in a tub, flesh side up, with more of the curing agent scattered over each layer.

The salmon are left to cure for two to three days, then removed, rinsed, and wiped clean. Three or four thin double-pointed sticks are fixed through the skin at intervals along the back to keep the salmon spread out flat. They are then hung in a shady place with a good breeze until dry. This will require about a week to 10 days. The fish are not brought in at night unless the weather is damp.

This salmon is sliced thin for use in sandwiches or as an appetizer. Stevenson (1899) reports that brandy is sometimes poured over the dry fish and allowed to soak in to improve the flavor.

SHARK

The dry-salting of shark is carried on commercially in Florida, Cuba, Mexico, the Bahama Islands and some of the other West Indies and on both coasts of South America. Shark is also dry-salted in the Orient and in the South Pacific. Methods differ in some details in each locality where this fish is cured, varying according to personal ideas of the curers and differences in local conditions. The method described here is representative of curing practices in the United States, but may not be the only one in use.

Curing must begin within the shortest possible time after catching, as spoilage occurs more rapidly with the shark than with many other species. The shark is first gutted and skinned, after which the carcass is split into two sides, removing the backbone. The large streak of dark meat along the middle of each side is then cut away, dividing each side into two fillets of light-colored flesh. These fillets may be further divided into two or more pieces each, if the shark is very large. A single fillet or piece should not weigh more than 3 or 4 pounds. Each piece is then scored on both sides, lengthwise, with a knife. The pieces are dropped into a tank of clean sea water or saturated brine, to soak for about an hour (Jarvis 1943a).

The fillets are drained of excess moisture after brining, which requires 30 minutes. They are then rolled around in a shallow box half-filled with packers fine salt, which is rubbed well into the slashes in the flesh. The fillets are packed in a tub, in layers, with each layer at right angles to the preceding one. Salt is scattered between each layer of fish. The top is weighted down to keep the flesh below the surface of the brine which forms. The shark fillets remain in salt from 2 to 7 days, depending on size and weather. During unfavorable weather they may be kept in salt for 10 days or possibly even longer.

When the meat has been sufficiently salted, the pieces are scrubbed thoroughly in fresh brine, and laid in small heaps to drain for 2 or 3 hours. They are hung out to dry in a shady location having a good breeze, or are laid out on drying racks covered by a roof as a protection against the sun. Drying under the direct rays of the sun is apt to discolor the flesh, especially during the first days of the drying period.

At the end of each day the shark

fillets are stored in a dry shed or warehouse, piled up in small heaps with weights on top equivalent to about half the weight of the fish. The next day the fillets are again dried and in the evening stacked under weights with the pressure increased somewhat. The alternate drying and pressing are continued, with the pressure constantly increased until the cure is complete. This requires about 10 days (Caribbean Commission 1945).

If drying conditions are not good at the end of the drying period, the fish may be hung in a light smoke for one day (about 10 hours). The temperature should not be much over 80° F., and the density should not be sufficient to color the product to any extent. The fillets are packed in shallow wooden boxes, tightly covered. Sometimes each fillet is individually wrapped in paper or the box may be paper-lined, but this is not the general rule.

TUNA

Dry-salted tuna has always been an important Japanese fishery product. It is prepared in large quantities in Japan, to some extent in the South Pacific, and in California, being introduced into both of the latter areas by the Japanese. Either bluefin (*Thunnus thynnus*) or yellowfin tuna (*Neothunnus macropterus*) is used, but the yellowfin is preferred. This method is generally utilized in California to preserve surplus catches from the fresh-fish market.

The tuna are eviscerated and headed, then washed thoroughly. They are then cut into sides, removing the backbone. Each side is again divided into two tenderloins or fillets, cutting away the dark flesh along the lateral line. The fillets are washed thoroughly in clean sea water and are then soaked in brine for about two hours. The purpose of brining is principally to remove diffused blood from the flesh. The brine is believed to test about 50° salinometer. After brining, the fish are drained and each fillet scored with a number of longitudinal cuts on each side. If they are large, the fillets may be subdivided into two or more pieces each, cutting both longitudinally and in cross sections. If a fillet is too thick it will not cure properly.

The individual pieces are rolled in salt, rubbing it well into the cuts or slashes in the flesh. Any salt readily available is used. The pieces are picked up with as much salt as will cling to the flesh and packed in layers in tubs or salting vats, with an additional scattering of salt over each layer. They are left in salt from 5 to 10 days, depending on the size of the individual pieces, and on weather conditions. The fillets may be kept in salt longer than 10 days if there is an extended period of unfavorable drying weather.

When the pieces are considered struck through, that is, when the salt has penetrated the flesh completely, they are washed thoroughly in clean sea water and laid out to dry in a shady location exposed to a good breeze. If dried under the direct rays of the sun the color will be darker, the flavor stronger, and the product will not keep so long.

The fish are gathered up every evening so that they will not be exposed to the night dampness. Some curers stack the fish in small heaps at night, and these are weighted down. This presses a small additional amount of moisture from the fish. From one to two months are required for drying. When completely dried, the tuna are sprinkled with fine salt, the pieces are wrapped in paper and packed in light wooden boxes.

MOJAMA

In Spain, salted and dried tuna is prepared under the name of "mojama" (Uriarte 1926). The lean meat from the area of the backbone of unspawned tuna, called "descargamento," or any portions of the flesh of spawned tuna except the belly flesh, is cut into strips 5 centimeters (2.0 in.) thick and 50 centimeters (19.7 in.) long. The dark meat along the lateral line is trimmed away. The fillets are washed more or less thoroughly in sea water. After draining off the surplus moisture they are rolled in coarse fish salt (usually Cadiz), then salted down in kenches about 1 meter (3¼ ft.) high, with salt scattered over each layer of fish until covered. The tuna are left in salt from 24 to 36 hours. They are then washed thoroughly in clean sea water, and any salt crystals are scrubbed from the flesh. After washing four times, the strips are allowed to soak for a few minutes and then drained.

A sharp stick (usually a sliver of split cane) is run through the flesh of each strip near one end. A string is tied to the stick on each side and the strips of tuna, called "mojama," are hung by the loop formed, from overhead poles running horizontally across the open air drying ground. A temporary roof of rush mats is usually erected over the drying rack. The mojama must be dried in the shade, as it turns rancid almost immediately if dried under the direct rays of the sun. The mojama is allowed to hang until it is perfectly dry, which may take two or more weeks. Dieuzeide and Novella (1942) give a minimum drying time of one week. When the pieces are sufficiently dry they are taken down, trimmed of any ragged edges, and packed for shipment in paper-lined wooden boxes.

Mojama of good quality will have a black-red color and a fresh smell, not the pungent odor characteristic of the anchovy cure. It is considered a great delicacy as an hors d'oeuvre. Mojama is served cut in thin slices together with sliced Spanish onions. A little olive oil may be poured over the mixture.

DRY SALTING FISH IN WARM CLIMATES

PREVIOUS STUDIES

In subtropical or tropical climates it is difficult to cure fish, especially if it is to be kept for any length of time. Yet it is in these areas that there is the greatest need for protein, and fish is the best potential source. The natives of the Asiatic coasts, especially China and Japan, have made some progress in developing fish curing under subtropical conditions, but have not solved the problem. The solution of the problem of fish curing in warm climates is considered of great economic importance, for it would raise the nutritional standard of the people and also increase employment.

The Bureau of Fisheries (now the Fish and Wildlife Service) made extensive researches on the problem of fish curing in warm climates. The first by Tressler (1920), paid special attention to the physical and chemical factors involved; later Jarvis (1932 a) studied operational problems in the field. As a result of these studies, it was found that it was possible to cure fish of good quality that will keep for an extended period in tropical and subtropical climates. But, it is not always practicable to create a fish-curing industry of considerable size under tropical conditions. A small local surplus may be preserved, however. In some localities, especially on the coast of Brazil, Chile, Venezuela, and possibly in sections of Africa there may be some prospects for fish-curing on a commercial scale.

Location Requirements

The method developed for fish curing in warm climates is a variation of dry salting. It is successful only when the essential points are followed closely, and if great care is given to every step in the manufacturing process. The location for the drying racks should be on dry ground on a point where there is a good sweep of breeze. All vegetation should be cleared away and the ground covered with gravel. Large areas of nearby swampy land are undesirable, but small swampy patches may be filled in. There should be an ample supply of fresh water of good quality. The use of salt water dipped up along the shore is undesirable since it is almost always heavily contaminated. Sometimes, however, it is necessary to use sea water, then all possible sanitary precautions should be taken. There should also be adequate measures for the prompt disposal of all waste, which should be burned, if possible, or at least be buried immediately.

Species Suitable for Curing

Not all varieties of fish are equally suitable for curing. In general, the white fleshed, nonfatty fish give the best results. In experimental work conducted by the Fish and Wildlife Service the best products were made from barracuda, parrotfish, snappers, and shark. Bonito and crevalle, or carang, make dry-salted products possessing good texture, flavor, and odor. The only objection is that the flesh is rather dark colored. Fish such as the corbina and robalo make a good product, but are usually in such demand in the fresh fish market that they are not available for curing.

Handling Raw Material

Careful handling is required from the moment the fish are caught. If possible they should be packed immediately in ice in the round (ungutted), using about 50 pounds of finely crushed ice to 100 pounds of fish. Since ice is often unobtainable in fishing villages in warm climates, the fish may be stored in a box with a top, and possibly two sides of heavy burlap, or similar material. The burlap is kept moist by dripping water on it occasionally until the catch can be landed. Evaporation produces some degree of coolness.

Gutting is advisable only if done thoroughly, scraping out all traces of blood and viscera, rubbing the belly cavity with a small amount of salt, and scattering salt over the skin. Gutting, in which the false kidney and some remnants of viscera are allowed to remain, does not reduce the rate of spoilage.

The fish should not be allowed to remain under the direct rays of the sun without protection. If tarpaulins or other covers are used, they must not rest directly on the fish. Air circulation is essential. It is also necessary to begin curing within a few hours after the fish are caught, especially in the daytime, and where ice is not used. In some instances, spoilage has been noted by the author within 3 hours after catching.

Dressing and Splitting

The fish should be dressed as landed. First, they are washed in a 40° salinometer brine. If a salinometer is not available a solution made of 1 part salt to 9 parts water is roughly equivalent. Washing is necessary to remove slime, loose scales, sand, seaweed, or other foreign material. The fish are then headed, gutted, and split after the method used for cod, but first the dorsal fin is removed from most of the larger fishes. This is best done by making a long cut through the flesh, along the entire length of the fin, and just at its base, on both sides. One end of the fin is then grasped and the fin is pulled away as a whole, with the short bones attached to its base. This is much quicker and easier than sawing the base of the fin. In most cases the other fins should also be removed. In cutting off the head the line of the gill flaps is followed. The napes or collar bones are not cut off, as this increases loss of weight, makes the fish harder to handle, and detracts from its appearance. A cut is then made just above the backbone, on the abdominal side, cutting along a line where the rib bones join the backbone. This is continued almost to the tail, holding the edge of the knife blade at a downward slant so that no flesh will be left on the backbone. A similar cut is made just below the backbone. A sweep of the knife through the rib bones still adhering to the flesh removes the backbone, which is broken off near the tail. These cuts must not reach through to the skin. When splitting is completed the fish should be in a single flat piece. Some of the largest fish, as for example the robalo and barracuda, may be cut into two separate sides. After dressing and splitting, all traces of blood or membranes are removed carefully. The flesh is then scored to a depth of about one-half inch, the cuts running longitudinally from napes to tail and at distances of from 1 to 2 inches apart.

Smaller fish, such as mullet and

Spanish mackerel, are split mackerel style; that is, the ungutted fish are split down the back just above the backbone. Sometimes the cut is made through the head, which is allowed to remain, but it is cleared of gills or other offal. Sometimes, especially for larger mullet and mackerel, the head is first removed. When the knife is drawn toward the tail, it must not go clear through the skin on the other side, so that the fish is cut in two pieces near the tail. The fish should lie flat in one piece. In splitting Spanish mackerel and other fat fish, the backbone is cut out nearly to the tail, where it is broken off. The "black skin" found in the bellies of mullet and some other fish is best removed by scrubbing with a piece of coarse canvas or sacking.

Brining and Salting

The fish are soaked for 30 minutes in a 40° salinometer brine, then scrubbed, and drained. The principal object of brining is to remove traces of diffused blood from the flesh but it also makes the flesh a little firmer and easier to handle. A third reason is that the fishes of warm climates have a quantity of slime, which is "cut" better by brine than by fresh water. At this point the fish are inspected for proper cleaning. If the backbone has been allowed to remain, a slash is now made just under the bone to obtain better penetration of the salt.

When the fish have drained from 15 to 20 minutes after soaking, they are ready for salting. The fish are dropped singly into a shallow box about 3 feet square and with sides 6 inches high, the dimensions varying according to the average size of the fish. Salt is rubbed into the flesh and the fish are dredged in the salt, paying particular attention to filling all cuts or slashes with salt. They are then lifted up with as much salt as will cling to the bodies, and packed in a vat or tub, skin side up, arranged in even layers with a scattering of salt on each layer of fish. Each layer is packed at right angles to the one preceding. The top layer is packed skin side up and more salt is scattered over this layer than the others. The total amount of salt used should be from about 30 to 35 pounds a 100 pounds of fish. Fat fish require somewhat more salt than lean; large, thick fish more than small. In salting the fish a dairy-fine, or packers fine mined salt, with the lowest possible percentage of impurities, has been found best. Common sea salt is more apt to cause reddening, but if it must be used, it should be heated thoroughly by baking. Coarse salt pits the surface of the flesh, and does not dissolve so rapidly.

Brine forms naturally through the extraction of moisture from the flesh. Weights are placed on top to keep the fish under the surface of the brine. A saturated brine should be added if sufficient brine to cover the fish has not been formed in 3 hours.

Drying

The salting shed should be light, dry, and as cool as possible. The fish are kept here in the salt brine for a period of 48 hours. The fish are not "struck through"; that is, the salt has not penetrated completely, but after considerable experimenting with varying periods it was found that fish absorb sufficient salt for curing purposes in an average of two days. Some fish, especially the smaller ones, such as mullet, require only from 24 to 36 hours in salt. On removal from the salting vats, the fish must be scrubbed in brine to remove all traces of excess salt and dirt. After draining for 20 or 30 minutes the fish are ready for the drying racks. These are frames of wood, covered with chicken wire, if available; if not, with an openwork screen of bamboo or cane.

Oxidation, rusting, or sunburning sets in immediately in warm climates if drying is carried on under the direct rays of the sun. However, if fish are kept shaded, in a breezy location, they will dry well, with a clear color, and will not oxidize readily afterward. For this reason a roof must be erected over the drying racks and the whole drying area located so that the maximum amount of breeze will sweep across the fish (fig. 17). The fish are first laid out skin side down, but are turned at hourly intervals or at least three or four times during the first day of drying.

Handling During Drying Period

The fish are gathered up and placed under shelter at night, for two reasons. First, if left spread out in the damp night air they may sour or mold and will certainly take much longer to dry. In the second place, moisture is "sweated out" while in a shelter protected from rain, fog, or dew. The fish are stacked in two rows to each layer with the tails to the center and the napes to the edge of the rack, skin side down, except for the top layer, on a low slatwork rack about 6 inches high. The stack is covered with matting if there is any doubt that the shed is not dry enough. Weights are placed on top of the stack to press out additional moisture. Additional weights are added each night as drying progresses.

The time required for drying depends on weather conditions and the size of the fish to be cured. It is, therefore, not advisable to attempt to give the exact length of time required for air drying. In the experimental work conducted by the U. S. Bureau of Fisheries (now the Fish and Wildlife Service), 45 hours of air drying, or about 5 days in total time, was a fair average for the drying period. Therefore, due to the many variants, such as changes in weather conditions and size of the fish, the time required for drying must be determined by the curer through practical packing operations. The fish may be considered cured when no moisture is apparent on the surface, and a thumb pressed into the thick part of the flesh makes no impression. The fish must be dried down to a moisture content of not more than 25 percent.

Preventing Insect Infestation During Drying

If the weather is still, especially during the first part of the cure, a trench should be dug along each of the two long sides of the drying roof. Fires are built in these pits,

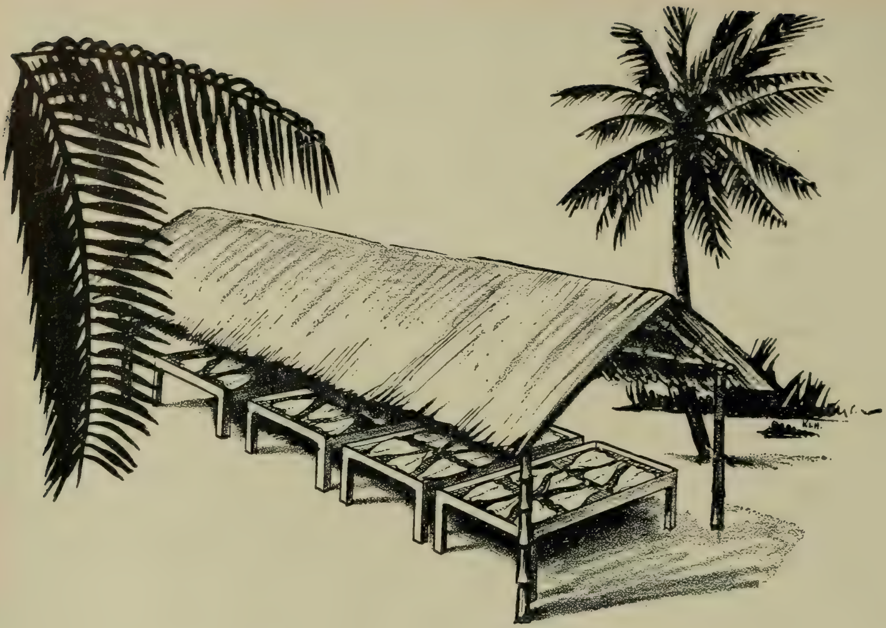

Figure 17.—Drying salt fish in warm climates.

which are then smothered to form a smudge with green coconut-leaf ribs or husks, or branches from aromatic shrubs. This drives away flies which would otherwise infest the fish flesh with maggots. If humid, still weather sets in when only a few hours of drying are needed to complete the cure, or if the fish have been pressed and repressed in the kench (stack) for several days and no change occurs in the weather, so that they can be air dried, the following method of drying may be used.

Heat Drying

Light movable walls of matting, bamboo, or thatch are constructed and set in place to close in the roof over the drying racks. Low fires of materials such as dry-coconut husks or dry hardwood are kept going in the pits so that there is a clear fire without much smoke. Doors of the drying shed are left open in the direction of any air movement. The fish are spread out on the racks and turned regularly every two hours. The fires must not be allowed to blaze, and the temperature at the level where the fish are laid out should be less than 100° F., or the fish will be scalded. If a thermometer is not available, a good rough test is to stretch out a hand among the fish, and if the air feels distinctly warm on the hand, the temperature is too high.

While not so good a quality as if air dried naturally, the product will be acceptable and better than fish cured locally by the old methods.

Handling in Storage

Dried fish should be stored in wooden boxes lined with tin plate, metal foil; or, failing these, with wax paper. They should be inspected at regular intervals while in storage. If there has been a period of damp weather, and the dried fish show signs of moisture, they should be given a few hours of air drying. If signs of rust or mold appear, the fish should be scrubbed in a light salt brine containing some vinegar, then spread out to dry in the air for a day or two.

MISCELLANEOUS BRINE PACKED FISH

At one time brine salting was relatively unimportant in comparison with dry salting, but both methods are almost equally important today in the United States. Cod is the most important dry-salted product; salmon the most important brine-packed product.

There is some confusion as to a definition of brine salting. According to Tressler (1920), brine-salted fish are cured by holding in a concentrated salt solution in a watertight container, while dry-salted fish are packed in watertight containers with an excess of dry salt. However, fish cured by the latter method cannot always be considered dry salted, and while pickled and mild-cured salmon are cured by placing them in watertight containers with an excess of dry salt, this is merely to allow the brine to form naturally by the extraction of moisture from the flesh by the salt. These salmon are cured and afterward held in brine. They are in dry salt only in the first stages, before curing has begun. Conversely, alewives or river herring are placed in a saturated brine, but as soon as it has penetrated they are packed in dry salt and held in dry salt until consumed. A product made in this way should really be considered dry-salted.

It is believed that the following definition is more accurate. Brine-cured fish are fish cured in a brine solution, either formed naturally by extraction of moisture from the flesh by dry salt or manufactured from salt and water, and held in brine until consumed.

Whenever possible, brine should form naturally by packing the fish in dry salt. This is in accord with the phenomenon of osmosis discussed under the section on Principles of Fish Salting. Enough brine to cover the fish will usually form in about 12 hours or less. In warm weather the fish are more liable to spoil than if they had been placed immediately in manufactured brine. Packing fish in dry salt requires more skill than is necessary in the brine curing method. It seems simple enough to add an excess of salt, but if that excess is too great the fish will be burned. The coarseness of the salt, the temperature and humidity, the composition of the salt, and the quality of product desired, must be considered.

Brine-packed fish can be freshened to a condition more like that of fresh fish than may dry-salted fish. The moisture content of brine-salted fish is much greater than that of dry-salted fish, so that loss in manufacture is less and consequently raw material costs are lower. The disadvantage of brine salting is that the product is less convenient to transport and distribute. Brine-packed fish require special storage if they are to be held for more than a short time. Brine-salted fish are not nearly so durable as dry-salted fish and they spoil quickly in warm climates, while dry-salted fish cured to a moisture content of 30 percent or less, will remain in good condition over a much longer period. Dry-salted fish are not so dependent on cooperage and storage as are brine-salted fish. In long-period storage, where special low temperature storage is available, fish stored under brine change much less than dry-salted fish, when both are held at the same temperature.

ALEWIVES OR RIVER HERRING

Alewives or river herring are of two species (*Pomolobus pseudoharengus* and *P. aestivalis*). They are salted commercially in Maine, Massachusetts, Maryland, Virginia, and North Carolina. North Carolina and Virginia produced 5,742,000 pounds of salt river herring in 1940, or 81.4 percent of the total pack for that year. The pack of salt herring has decreased in recent years, not so much as other cured products, because of decrease in demand, but because the preparation of vinegar salt-cure herring has taken much of the supply of available raw material. A great quantity of salt herring is now marketed as corned rather than as tight-pack herring, which was formerly the standard pack. The curing of river herring as conducted in the Chesapeake Bay area is regarded as representing the best commercial practice. This has been described fully by Jarvis and Hines (1943).

Catching, Handling, and Landing

River herring, or alewives, salted in the Chesapeake Bay area, are caught in fish traps, locally called pound nets. If the distance to the fishing grounds is not too great a portion of the catch is brought to the processing plants in the boats used to fish the traps. These fish reach the packing house on an average of 5 hours after they are caught. The remaining fish are brought in by run boats. The load of run boats or transporters includes fish obtained from nets at some distance from the saltery and the catches of a number of trap operators, each with a single net, who are dependent on these boats to handle their catch. The fish brought in by run boats, as a rule, have been out of the water from a minimum of about 12 hours to a maximum of 24 hours. Under ordinary weather conditions a salted product of good quality cannot be prepared if the herring have been held longer than this time before salting, though should the weather be unusually cool, between 40 and 50° F., the time in which the fish will remain in good condition may be extended to 36 hours.

River herring are bought by count. The price averaged five dollars per thousand in the years just before our entry into World War II. The fish are unloaded from the hold of the transporting boat by bucket hoists. A bucket will hold about 500 fish. An occasional bucket of fish is counted to establish the number held by the container when it is filled level with the brim and to determine the proportion of scrap fish. These are usually small menhaden or croakers and are discarded, with no payment to the fisherman.

Washing and Butchering

The bucket is emptied into a hopper leading to a washer, which consists of an inclined revolving, wire-mesh drum with a perforated pipe running along the axis. One-inch angle irons are fixed at 1 or 2 foot intervals along the inner circumference of the drum to act as baffles. As the fish are carried through the drum the scales are removed by the tumbling action. Sprays of water from the perforated pipe wash the fish at the same time. The fish are carried by overhead conveyor from the washer to the cutting table. Details in cutting-table construction differ from plant to plant, but a typical table stands about 4 feet high, with a width of some 8 feet. It rises to a peak in the center with a 1-foot slope to the sides. The fish fall from the conveyor onto the peak of the table then slide down toward individual pens where they are cut.

Each workman is provided with a wire fish-basket and an enamel or galvanized-metal water bucket. The herring is grasped around the back near the head, and the workman makes a single curving cut, starting at the back of the head just behind the gills and continuing down the belly to the vent (anal opening). This removes head, viscera, and thin ventral flesh in one operation. The cut fish is thrown onto the wire basket. If the herring contains roe, this is separated from the viscera and dropped into the galvanized bucket. If the cutting is not done carefully, some viscera may be left in the body cavity or the roe may be damaged by cutting. A large part of the cut roe is lost in canning, since it drains away in washing. Cutting is done on a piecework basis, the workers being paid a certain price for each basket of cut fish or bucket of roe.

After cutting, the fish are thrown into washing tanks. A typical tank is made of 2-inch pine planks and is about 12 feet long, 6 feet wide, and 3 feet deep. Some tanks are constructed with the bottom inclined about 30 degrees to one side, and a false bottom of slats, spaced one-half inch apart, is placed in the tank at the top of the incline. Scales, viscera, and other waste material settle down in the deep angle of the bottom. Waste is drawn off with the water through an outside pipe or flood gate. This type of tank is good because it requires less time to clean than an ordinary flat-bottomed tank, and waste is more readily separated from the fish. The fish are stirred about in the water of the washing tank for about 10 minutes, making washing more thorough. The stirring is done mechanically in some plants, but hand labor is still used in a number of salteries.

Salting

When the herring are sufficiently washed, they are scooped out of the tank with dip nets into slat cars holding about 1,200 fish and carried to the salting vats. In some salteries wheelbarrows with high sides are used for this purpose. Excess water drains away as the fish are carried to the vats. These vats are shallow wooden tanks built of 2-inch Virginia pine. They are usually 10 feet long, 6 feet wide, and 3 feet deep. Before any fish are put in, brine testing 100° salinometer is poured into each tank to a depth of about 4 inches. As each load of fish is emptied into the tank, additional salt is added, the exact amount varying with the condition of the fish, humidity, and temperature, but averaging about 700 pounds to a tank. When full a tank contains from 12,000 to 15,000 fish (about 4,000 lb.), and the brine should test from 95° to 98° salinometer. The fish should be roused; that is, stirred about once each day while curing. After each rousing they are pressed down lightly in the tank and a thin layer of salt is scattered over the top. About 25 pounds of salt are added each time this is done.

Cut or clipped herring require about 9 days to cure. In fact a curing period of this length is the required standard under Virginia packing regulations. Roe herring cured with only the heads removed must be salted 14 to 15 days. Strength of the brine is checked daily and should test not less than 90° salinometer. If it falls below this level, additional salt should be added.

Sufficiency of cure is determined first by the odor, when the flesh is pulled from the backbone. The odor should be good, without suggestion of sourness. The flesh should be firm, but not excessively hard, the skin only slightly wrinkled and the blood under the backbone should be dried.

Packing

When cured, the fish are taken from the tanks and piled in heaps on the floor of the packing shed to drain. It is recommended that draining racks should be at least 6 inches above the floor. The herring should not be piled in heaps more than 18 inches high. The fish should be drained from 4 to 7 days. The herring are then weighed or counted and packed in tight, heavy barrels. The fish are filled into the barrels in wheel-like tiers; that is, radiating from the center, with the first layer packed backs down, and all other layers with backs up.

A layer of three-quarter-ground salt is scattered over each layer of fish, using about 2½ pounds to the layer. A properly packed barrel should contain 160 pounds of fish and 50 pounds of salt, with an average of 600 to 650 herring by count. The variation in count between barrels in any one lot must not be more than fifty. The cured fish should measure not less than 6 inches if headless, or clipped, while whole fish should not measure less than 7½ inches.

The barrel head is pressed in and the container headed up. It is then marked with the packer's name or brand, and sometimes with the approximate number of fish. No brine is added, so that this pack, while brine cured, goes into consumption as a dry-salted product. This cure is known as tight pack. It is subject to oxidation after a few months of storage at ordinary temperature.

Corned Herring

The fish may be taken out of the tanks after they have been in brine from 12 to 48 hours. When this is done they are usually drained from 5 to 24 hours, although some packers do not drain the fish at all. The drained herrings are packed in bushel baskets with about 250 fish to the basket. As a rule no salt is added. The baskets of fish are sold to grocers, or hucksters who peddle them throughout the countryside. This product is called corned herring and when boiled or fried is a favorite springtime breakfast dish in the southeastern United States.

Much of the salted river-herring are given the full 9-day cure, after which they are hauled in bulk to Richmond where they are stored in brine, and held throughout the year in chill storage at 34 to 36° F. until sold to the retailer. Then the fish are drained for a few hours and packed in bushel baskets as described above. They are sold as corned herring, though they are more heavily salted than the corned herring described previously. This pack answers the demand of the retailer for a smaller package. It is brighter and more attractive in appearance than the tight pack which it may displace entirely. Corned herring will remain in good condition from 10 days to 3 weeks in the hands of the retailer, the time depending on the length of cure, and on the temperature.

Inspection and Grading

A large part of the herring cured in Virgina are packed under a voluntary inspection system administered by the Division of Markets of the State Department of Agriculture (Jarvis and Hines 1943). Under this system the packer agrees to maintain certain standards of pack. His fish are regularly examined by qualified inspectors while curing to insure that the process is being properly done. The inspectors keep complete daily records of temperature, salinity of brine, condition of fish, and any other factors which may affect the cure. The inspector is present when the cured fish are packed for shipment to insure compliance with the accepted standards. If the pack is satisfactory, a grade certificate is isued to that effect, and the inspector stamps each container with the official grade stamp.

The grades are as follows:

Virginia No. 1 Herring—shall consist of fish of one species, taken before spawning, fresh when curing begins, bright, free from rust at time of packing, of a sweet wholesome odor, thoroughly cured, well drained, with 80 percent of scales removed, and free from damage from any cause. All clipped roe fish shall have the heads properly removed. All roe fish shall have a fairly developed roe.

All cut fish shall be properly cut, thoroughly cleaned, and washed before curing begins.

Virginia Selects—shall consist of fish that meet all the grade and packing requirements of Virginia No. 1 and in addition shall, when clipped, have all membrane and blood removed from under the main bone. All roe fish shall have a well developed roe.

Unclassified—shall consist of fish which are not graded and packed in conformity with the foregoing grades.

This system of inspection has done much toward raising the quality of the Virginia pack and to establish it as a high grade salt fish product.

COD

Brine Packing

On the Atlantic coast, brine-packed cod (*Gadus morhua*) is prepared commercially in small quantities, for local distribution. This is done principally by shore fishermen in the State of Maine. On the Pacific coast, brine-packed cod (*Gadus macrocephalus*) is packed in the Puget Sound area and in Alaska. In addition to the local market, some brine-packed cod is shipped to the Scandinavian-American trade of the Middle West. Commercial fishermen on both coasts prepare this pack for their own use; the fishermen themselves preferring these fish since they rehydrate more readily, and have a flavor and texture superior to dry-salted cod.

On the Atlantic coast, pollock (*Pollachius virens*) also are prepared by brine curing. Haddock (*Melanogrammus aeglefinus*) were once brine packed to a considerable extent but this use is only occasional today. Hake and cusk are rarely, if ever, brine-packed commercially. The method is the same for all groundfish.

Butchering and Salting

The fish are dressed, split, and washed as for dry-salting. Large fish are sometimes split into halves. When the washed fish have drained sufficiently, they are salted in butts or hogsheads as when preparing for dry-salting. It was formerly customary to call for a special curing salt such as Liverpool, Trapani, or Lunenburg. This is no longer true. Any good commercial salt may be used provided it has a medium-size grain; three-quarters ground salt is preferred.

A thin layer of salt is scattered on the bottom of the hogshead. Salt is rubbed into the flesh and the fish are packed into the hogshead flesh side up. A scattering of salt is thrown over each layer of fish taking particular care that salt is present where fish overlap each other. Each layer is packed at right angles to the preceding one. The top layer of fish is packed skin side up, and a heavier layer of salt sprinkled on top. The top may be weighted down to keep the pieces of fish submerged after the brine forms. The top should be covered with brine in 24 hours or less, but at least a week will be required for the fish to be struck through or cured. An experienced curer can determine this by the appearance of the flesh. Salt is used in the proportion of 35 pounds to 100 pounds of fish (Jarvis 1944b).

Repacking

The cod are allowed to remain in brine until required for sale. They are then removed and repacked in barrels holding 200 pounds, half barrels of 100 pounds, and kits or tubs holding 25 or 50 pounds. Each piece of fish is scrubbed as it is repacked in the container and a small amount of salt is scattered on each layer of fish, using 15 to 20 pounds of salt per 200 pound barrel. After the barrel is headed, it is filled through the bunghole with brine testing at least 90° salinometer. The product ships quite well, and does not require special handling in storage when the barrels are tight and the brine does not leak out.

Some of the smaller operators pack the cod directly in shipping containers after splitting, adding salt in the proportion given above. Brine forms naturally. When the cure is completed and the fish have settled down in the barrel, a few more fish of the same day's cure are added to the top. The barrel is then headed up. Some curers also drain off the brine formed in curing, refilling with fresh 100° salinometer brine.

Pickled Cod European Method

It has been reported that brine-salted cod of higher quality than that prepared in the United States has been packed in some of the European countries. Brine-salted cod (or pickled, as it is called in the British Isles) is cured in greater amounts and is more popular than in the United States. It is packed commercially in Holland, Scotland, Sweden, Belgium, and France. The choicest pickled cod are reported to be prepared in Holland. The method given here is a summary of the best European commercial practice. The method used varies in Holland, Scotland, and Sweden, only in such points as the type of salt used or in the minor details of splitting.

When possible, the cod are bled as soon as caught. They are headed and gutted at once when received at the curing plant and put into clean fresh water. The fish are then washed and cleaned thoroughly. After draining, the fish are ready for splitting, which is considered to be a very important factor in preparation. The recommended practice is as follows:

The gutted fish is laid on the butchering table with its tail toward the splitter, who takes hold of the upper napes of the cod with his left hand, enters the knife at the vent and draws it down to the tail above the bone. He then gives the fish a half turn, its tail falls outward and the shoulders swing inwards till the back is turned towards him. He raises the napes with his left hand, makes a cut just above the end of the backbone at the head end, and with the knife blade at a downward angle, carefully splits the fish from the bone, leaving as little flesh on the bone as possible. The split fish is given another half turn so that the head is toward and the tail away from the splitter. He steadies the fish with his left hand and carefully runs the knife down under the backbone, with the edge of the blade at a slight upward angle, separating the backbone from the flesh. The backbone is cut off a short distance above the tail. The cut is usually made through two vertebrae at an angle.

The outer ends of the rib-bones, if still adhering to the flesh, should be carefully cut, not torn away. A slash is made just under the remaining backbone, so that it may be bled properly, and the salt may penetrate more readily.

The next step is cleaning. The black skin or belly membrane is removed and any bits of viscera, coagulated blood, or ragged edges of flesh or skin should be carefully cut away. The fish is then washed thoroughly in clean water, using a scrubbing brush both inside and out. The washed fish are piled in small stacks, skin side up. The stacks are covered with boards and weighted down lightly. The fish are left in the stacks about two hours. This is considered more effective than ordinary draining and also presses out diffused blood not removed in washing.

The cod are then salted into butts or tierces. A scattering of salt is thrown on the bottom. The first layer of fish is laid in skin side down. A thin layer of salt is then added. It must be spread evenly and the fish must be completely covered. The second layer of fish is packed in at the same angle as the first, the flesh side down. The third layer of fish is packed at right angles to the first two, with flesh side up. The fourth layer of fish is packed at the same angle as the third with flesh side down. This is done so that the flesh in salting will not be discolored by the skin pigment of the fish in the layer above. The amount of salt to be used depends to some extent on the season, the size and thickness of the fish, and the length of time they are to be held before marketing. As a rule an average of 84 pounds of salt are used to 250 pounds of fish.

The cod are left in the curing vats for 48 hours, then taken out of the brine and washed carefully to remove slime or excess salt. After washing they are laid out on a packing table, flesh side down. Any wrinkles are smoothed out carefully. Anal fins should be cut away neatly and dangling tags or ragged edges of flesh or skin should be pared off, to give a neater appearance. As the fish are trimmed they should be graded into two or three different sizes, each grade to be packed into separate barrels. The number of fish contained should be marked on each barrel.

The barrels should be wet thoroughly before use. A scattering of salt is thrown on the bottom. In packing the fish the packer must lift and handle them carefully so as not to damage them. Duthie (1911) reports that the best way is to grasp the tail of the fish with the right hand and its shoulder with the left, the skin of the fish being downward. The fish will thus fall in a partial fold and allow for its being put inside the barrel easily. The bone of the fish should be laid next the side of the barrel. Two medium-sized fish will make a tier laid head and tail alternately (fig. 18). The layers are laid in flesh side up except for the top layer, and at right angles to each other. If the fish are to be used at once no salt is needed between layers, but as the length of time required for shipping and retailing is

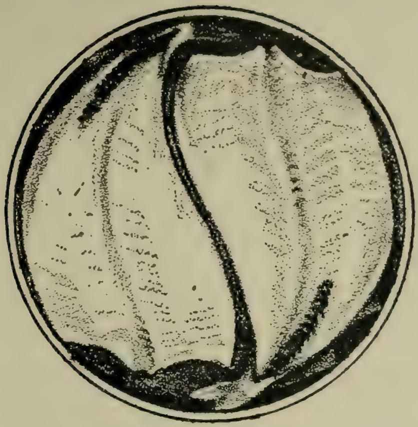

Figure 18.—Brine-packed cod showing arrangement in the barrel.

uncertain, a sprinkling of salt is advisable between layers. This amounts to about 15 pounds to the barrel.

When completely filled, the barrels are headed up and a bunghole bored in the bilge of each one. The barrels are filled with fresh strained 95° to 100° salinometer brine through the bungholes. If held in storage the barrels should be inspected regularly to see that they are full of brine. If held for longer than 6 weeks the fish should be repacked before shipping. If necessary they should be washed and trimmed again and the barrels filled with fresh brine.

Cod Tongues

Cod tongues are considered a delicacy, especially by New Englanders, Nova Scotians, Newfoundlanders, and Scandinavian-Americans. While most of the preparation and preservation of cod tongues is for home use, they are also cured commercially. The commercial production of salted cod tongues in the United States was 44,000 pounds in 1943.

Cod tongues are saved if the butchering crew is not too busy. In the vessel fishery one of the dressing gang usually cuts out the tongues, while at shore stations a boy is hired to do the work. The tongue is attached to the lower jaw, and when cut includes all that part of the jaw lying inside the jawbone. To cut out the tongue the workman takes hold of the fish by the back of the head, using the bony eye-sockets for finger holds. As he lifts the fish by the head its mouth usually falls open, then with his other hand he cuts the tongue loose on the sides with a sharp knife, following with a cut along the curving bone forming the back part of the lower jaw. The tongue is hanging by a thin strip at the forward of the lower jaw from whence it is torn loose by hand. The tongues are washed thoroughly in clean sea water and trimmed of any loose skin or fragments.

After draining, the tongues are mixed with salt in barrels following the proportions of 25 pounds of salt to 100 pounds of tongues. The tongues must not be oversalted or they will soon become hard and have an acrid flavor. Brine is formed by the extraction of moisture from the tongues by the salt. The tongues require an average of 10 days to become struck through, that is, for the salt to penetrate completely. When the tongues are sufficiently cured they are rinsed in light brine and repacked in barrels, with 200 pounds of tongues, net weight, to the barrel. The containers are headed up, after which they are filled with 100° salinometer brine. Wholesalers or jobbers again repack the tongues for sale to retailers, using half barrels holding 100 pounds of tongues; kegs, with net contents of 50 pounds; pails holding 25 pounds; and kits or small pails holding about 10 pounds.

For table use, the tongues are soaked for several hours in fresh water to freshen, wiped dry, rolled in beaten egg and cracker crumbs, and fried. The salt tongues cannot be held for more than a year even if well cured. The tongues gradually harden after about 9 months in salt, becoming inedible (Cobb 1926).

LAKEFISH

The lake herring (*Leucichthys artedi*) is the only fresh-water fish cured in large quantities by salting in the United States. The production was 5,037,000 pounds in 1940. This is about 32 percent of the catch for the year as there is a loss of approximately 30 percent in salting. Lake herring are salted along the shores of Lake Michigan, Lake Huron, and Lake Superior. According to the United States Tariff Commission (1927), the bulk of the lake herring salted in the Lake Michigan and Lake Superior areas is cured by the fishermen. The salt fish companies as a rule supply the fishermen with barrels, salt, and any other necessary materials and buy the salt fish as cured, for final preparation. On Lake Huron the fish companies usually do their own curing. Some of the Lake Michigan fish companies also do their own curing. The most important types of gear used in catching lake herring are trap and pound nets in Lake Huron and gill nets in Lake Michigan.

Lake herring for salting are brought into the fish house as soon as possible. During the summer months ice must be used on the fishing vessels to keep the fish in good condition. The herring are dressed and cleaned as soon as they are brought ashore. The head is removed, then a cut is made down the belly to the vent and the fish are eviscerated. The loss of weight in dressing averages 18 percent. The fish are thrown into a box as they are cleaned. When the box is filled it is emptied into a wash trough of fresh water and washed thoroughly to remove any blood, slime, or other offal.

When sufficiently washed, the lake herring are removed from the washing tank by a dip net and emptied onto the center of a salting table so constructed that the water will drain way from the pile of fish in the center. The common procedure in salting is as follows: Five fish are picked up and rubbed with salt. Particular attention is paid to the belly cavity. The fish are then packed together, back to belly. The salted fish are placed to one side and the process is repeated with another 5 fish. When 25 fish have accumulated, they are packed belly side up in a half barrel (capacity 125 lb. of fish). The method of packing is the same as for the sea herring (split-cure). A thin layer of salt is thrown over each layer of fish.

The salted herring are packed to a level of 4 inches above the barrel top, as there is considerable shrinkage in salting. The brine is allowed to form naturally. After standing for 12 to 24 hours, sufficient moisture has been extracted so that the barrel may be headed. From 7 to 10 days is required for the salt to penetrate completely, or "strike through" the fish. The herring are now known as "slime" fish. They may be repacked within a few days after the original salting, or held in this first cure for a week or more. If the herring are to be held, the barrels are headed, filled with 100° salinometer brine, and placed in chill storage. The loss of weight in the first salting is 9 percent.

When the lake herring are to be repacked they are removed from chill storage and the barrels are emptied onto a draining table 6 feet square, with a capacity of 5 barrels of fish. When the original pickle has drained away, the herring are transfered to a weighing table in the amounts needed to fill the shipping container. "The weighing table and the draining table, the surfaces of which are on a level are placed side by side. Rapid handling of the fish is facilitated by having the weigher concentrate his attention on the one operation. The weighed fish are passed from the 'weigher' to the 'packer' by a revolving table, fitted with compartments. As a batch of fish is weighed it is thrown into one of the compartments, from which the packer on the opposite side removes it as the rotating table brings it within his reach" (Tariff Commission 1927).

With the exception of the top one, all the layers are packed backs down. Before the tops are fixed in place a small amount of salt (averaging 3 lb. per 100 lb. of fish) is added and the containers are filled with brine testing 100° salinometer. The salt lake herring are packed into kits or pails holding 5 to 25 pounds and in barrels with a net weight of 30 to 100 pounds. The loss of weight in repacking averages five percent, being less in winter and more in summer. The total loss of weight averages 32 percent of the original weight of the fish. The product should be held in chill storage if it does not go into retail consumption within a month or six weeks.

MACKEREL

Production and Imports

Brine-salted Atlantic mackerel (*Scomber scombrus*) also known as "Boston" mackerel, was at one time one of the most important fishery products in the United States. The peak of production in the industry was in 1830 when 449,950 barrels (99,990,000 pounds) were produced having a value of $1,862,000. The industry had its largest financial return in 1864 when the 324,454 barrel yield (64,990,800 pounds) had a value of $7,000,000 to the primary producer. Of the 131,939,255 pounds of mackerel taken in the United States in 1880, 80 percent was salted. In the 1880's, the 90's, and the early years of this century, salt mackerel was sold in almost every grocery store throughout the eastern States and the Middle West.

In 1940, which may be considered the last prewar year of normal production, the amount of Atlantic mackerel salted was 2,158,000 pounds, with a value of $135,669, while the total catch of Atlantic mackerel that year was 40,631,000 pounds. Split salt-mackerel was formerly the standard product. Two-thirds of the production now consists of salt-mackerel fillets. At one time the salting of mackerel was general throughout the New England States. It is now confined entirely to Massachusetts, with Gloucester as the most important production center.

Salt mackerel is also imported into the United States from Canada and several European countries, principally Eire and Norway. Some mackerel is salted in Great Britain, France, and the Netherlands. Mackerel imported into the United States is cured, packed, and graded by the American method, as the United States has been the principal market for the past hundred years. Imports of salt mackerel have decreased considerably. They amounted to 12,071,000 pounds in 1927 and 3,180,000 pounds in 1940.

Method of Catch

Mackerel which are to salted are caught almost entirely by purse seine. Trap-caught fish may be used at times. Formerly the bulk of the fish which were to be salted were cured at sea. The vessel cure was the typical method and is the one described by Stevenson (1899) and Tressler (1923). Today practically the entire pack is prepared ashore, utilizing the surplus from the fresh-fish market. Salting is done aboard the fishing vessel today only to save small catches which do not justify a run to port.

Butchering

The method of preparation is essentially the same whether at sea or ashore. Only fresh mackerel should be used for salting. Any attempt to "save" mackerel which is not quite fresh will result in an inferior product with a very rapid rate of deterioration. Since mackerel spoil readily, they should be handled as rapidly as possible after catching. If not split immediately, the mackerel should be iced, protected against the sun in warm weather, and should not be piled in heaps.

A dressing-gang usually consists of three men, one splitter, and two "gibbers," who eviscerate and clean the split fish. In Norway, the gills are sometimes removed before splitting. As the appearance of the fish when cured depends a great deal on the cutting, splitting must be done accurately. Sharp knives must be used for a clean cut. The mackerel are split down the back, as close to the backbone as possible, and on the left side. Each fish is laid on the splitting board with its head away from the splitter who begins at the head and runs his knife down above the backbone to the tail, cutting so that the mackerel will be flat and open in a single piece after the viscera are removed (fig. 19). For protection, and to prevent the mackerel from slipping the splitter usually wears a cotton or woolen glove on his left hand, which is holding the fish.

As each mackerel is split it is tossed to a gibber who opens the fish with a jerk, causing it to break along the lower end of the ribs, if it is fat, making a crease along each side. The gibber then removes the viscera and gills. If a fish is not fat he often "plows" or, as it is sometimes called, "reams" the mackerel. This consists of making a shallow cut in the abdominal cavity near each side of the backbone in imitation of the natural breaks occurring in fat mackerel. At one time this operation was done with the thumbnail but a special knife has been used for many years.

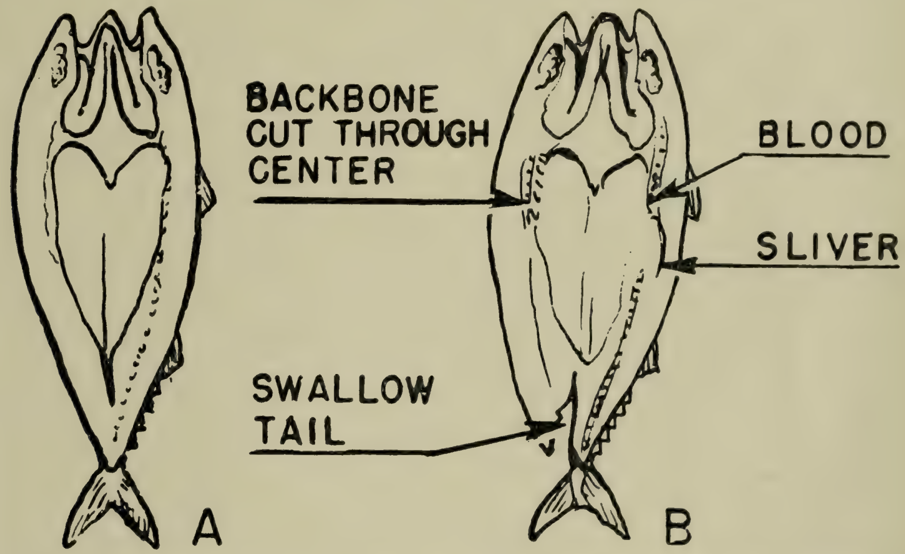

Figure 19.—Splitting mackerel for salting: (A) Properly; (B) improperly split fish. (Courtesy Dr. S. A. Beatty, Fisheries Research Board of Canada.)

Washing

Clean salt water is often used for washing. Tubs of clean water should be standing near the gibbers' end of the splitting bench, and each mackerel is dropped in the water as it is gibbed, with the fish open, and flesh side down. Ragged or soft fish should be discarded when splitting. Some curers prefer to leave the reaming or plowing of mackerel until the fish have been in water for some time. In washing the fish, care must be taken to remove all traces of blood, especially around the backbone. Some curers scrub out the blood with small brushes, but most of them clean out blood with the hands only.

The mackerel is a tender fish that requires careful handling during all stages of preparation to keep the flesh from being broken. In lifting split mackerel before it is completely cured, that is, salted, it is recommended that the hand should be placed below the fish which can then be lifted without being gripped. If handled at all roughly, the flesh has a ragged appearance when cured. Any protruding rib or other small bones must be cut off or plucked out with forceps.

As each fish is washed, it should be dropped into another tub of clean water. If possible there should be a steady flow of water through this tub. If it is necessary to use standing water, the water in the tubs should be changed three times for each batch of fish. The first water should be emptied at the end of 15 minutes, as the blood flowing from the fish soon colors the water, and if left in the tub for any length of time would discolor the flesh of the fish. The fish can be left a little longer in the second water, and can stay in the third water for about an hour. According to Stevenson (1899), mackerel were kept in the wash tubs to soak until all the mackerel were split, so that some mackerel may have been in the water for as much as 6 or 8 hours, or even longer. This is now considered poor practice, as the mackerel become too soft and are subject to breakage. The mackerel should not soak for more than 2 hours as a maximum. After soaking, the fish are rinsed by throwing buckets of water over them.

Packing

Only new barrels should be used in packing mackerel. Some curers try to economize by using secondhand fish barrels, but these containers are apt to give an unpleasant foreign flavor to fish. The Norwegians generally use barrels made of birch. American and Irish curers find barrels made of spruce satisfactory in packing mackerel. The mackerel barrel usually has an iron hoop on each end, with three or four wooden hoops made out of green withes.

The barrels should first be soaked in water to make sure that they are tight, for if leaky, or if the staves soak up too much brine, the fish will be exposed, causing "rusting" or oxidation, and spoilage.

After the mackerel have been rinsed and drained, they are placed, a few at a time, in a shallow tub partly filled with dry salt. The flesh side of each fish is rubbed in the salt, and they are picked up with as much salt as will cling to the body. A thin layer of salt is scattered on the bottom of the barrel. Then the first layer of fish is packed with the skin side down. The mackerel are packed in circular fashion, with the tails toward the center of the barrel. If there is a hollow space in the center, where the tails meet, one or two mackerel are laid across this space, to keep the layer level. A thin layer of salt is then scattered over the layer of fish. It is most important that every portion of the surface of the mackerel come in contact with the salt. After the first two or three layers, the mackerel are usually packed flesh-side down.

Salt Requirements

For salting mackerel, Americans and Irish generally use Liverpool No. 2, a finely ground fish salt, while Norwegians prefer Trapani salt. Coarse-grained fish salts such as Cadiz should not be used, since they pit the surface of the fish and give them a ragged appearance. If the mackerel are fat, 100 pounds of salt will be required for 300 pounds of fish. If fat fish are not heavily salted they will stick together in curing, making it impossible to separate without tearing. This would make them unsalable. If the mackerel are not fat, the proportion of one part of salt to four parts of fish will be satisfactory.

The barrel should be filled up to the croze, that is, the groove into which the head fits, with a heavier layer of salt than usual scattered on top. The barrel is then headed up, and a bunghole is bored in through the side. Strong brine (90 to 100° salinometer) is poured in through a funnel until the barrel is full. The bung is then driven in and the barrel laid on its side in a cool warehouse to complete the cure.

Curing and Repacking

From 10 to 12 days will be required to cure the mackerel, that is, to obtain the maximum penetration of salt. The barrels of salt mackerel are not rehandled but remain in storage until required for market. While in storage the barrels should be examined regularly for leakage and to see that they are completely filled with strong brine. The barrels are coopered, and additional brine is added as soon as any loss is detected. If the fish are allowed to become dry, they soon become soft and discolored, with a strong, unpleasant taste.

The mackerel are repacked carefully before shipping. The tops of the barrels are taken out, and the brine is drawn off and discarded. Then the fish are emptied, several barrels at a time, into a bin known as a "culling crib." It is a box of planed wood, about 5 feet long, 3 feet wide, and 8 to 10 inches deep, with a slat bottom, placed on legs 3 feet high. Here the mackerel are culled, or separated, into the commonly recognized grades. From the culling cribs the fish are thrown into weighing tubs. These tubs hold about 100 pounds each, and have network bottoms or a one-inch hole in the bottom for draining. When a tub is filled, it is weighed and taken to the packing cribs. The packing cribs are something like the culling cribs. The usual dimensions are 38 inches long, 26 inches wide, and 14 inches deep. The mackerel are packed into barrels, kegs, kits, or other containers from the packing crib.

Each grade of mackerel is kept separate and packed into separate containers. In repacking, the fish are filled in as in curing, with a layer of salt on the bottom and a handful of salt over each layer. The first two layers go in with the skin side down, all succeeding layers with the skin side up. About 36 pounds of salt are used in repacking each barrel, which should contain 200 pounds of cured mackerel, exclusive of salt and brine. After being filled, each barrel is headed up and moved to a convenient place in the warehouse, where it is filled with strong brine. The strength of the brine should be at least 95° salinometer. After a barrel is filled with brine, the bunghole is plugged and the barrel is set on end to be branded. The brand includes the name of the firm curing the mackerel, the net weight, number of fish in the barrel, the year, and sometimes the month when the fish were packed.

Quality and Grades

There is much variance in the quality of salt mackerel taken at different seasons of the year. The early spring catch is generally very lean and shrinks considerably when salted. The fish are fatter as the season advances, and those taken in the fall usually improve in weight after being placed in brine. Full-grown fresh mackerel measure 17 or 18 inches in length. The average length however, is about 12 inches and the weight a trifle less than a pound. Salted mackerel measure less due to shrinkage in salting.

The grades usually recognized in commercial practice may be defined as follows: Best quality, not mutilated, measuring, when split, not less than 13 inches from the extremity of the head to the fork of the tail, and free from taint, rust, or damage, are branded as No. 1. Mackerel of the same quality except that they measure as short as 11 inches are classed as No. 2. Second-quality mackerel but free from taint or damage and not less than 13 inches in length are graded as No. 3, large. Mackerel shorter than 11 inches, yet free from taint or damage are called either No. 3, small or No. 4. These grades have been put into the statutes of several of the New England States with little differences in specifications among States.

Salt Fillets

Salted mackerel fillets were first cured commercially in 1928. The salted fillets are now much more important in the salt mackerel trade than whole split mackerel. Fillets are prepared by cutting the head off just below the pectoral fins. A sharp knife is inserted just above the backbone at the head end. Then, keeping the blade at a slight downward angle, a sweep of the knife removes the upper side of the fish. The knife is then inserted just below the backbone and with the blade held at a slight upward angle, the backbone is removed, leaving two boneless pieces of fish. The thin edges of belly flesh are trimmed away.

The fillets are soaked in clean water, as in curing split mackerel, but are removed in a shorter time since the blood is more easily soaked out with the backbone cut away. The curing process differs little from that for split salt mackerel. The fillets are packed in barrels of the same size as used for split mackerel. The amount of salt used, averaging 30 pounds per barrel, is somewhat less than for split salt mackerel. The barrels are headed up, filled with brine, and laid away to cure. The loss in splitting and curing averages 50 percent.

The fillets are held under the same conditions as split salt mackerel until required for market. They are taken to culling cribs where the fillets are sorted for size, and any defective fillets are discarded. The fillets are repacked in kegs holding 100 pounds and tubs or kits with net contents of 10 to 50 pounds. The 10-pound kit is a favorite package. Little or no loss from shrinkage occurs in the repacking process.

MULLET

The striped mullet (*Mugil cephalus*) is the most important food fish of the southern coastal States. It is found from North Carolina to Mexico. This fish, or related species, is also found in Mexico and in Central and South America. The United States catch of mullet amounts to more than 30,000,000 pounds annually. Most of it is used fresh. From one to 2 million pounds are salted annually, mostly in North Carolina and Florida. Dry-salting is the method for curing mullet on the Gulf Coast of Florida, but on the Atlantic Coast of Florida and in North Carolina, brine-salting is used. Brine-salting was formerly more extensively employed, but as the result of a change in the food preference of the southern population, much of the market has been lost. Brine-salting is usually considered necessary with fatty fish because the fat is less apt to become rancid than in the dry-salting process. Attempts at brine-curing by curers who were both careless and ignorant of the proper methods, resulted in a very poor product and this was another important cause of the decline in the market. With improvement in preparation of the product, the trade could be re-established.

Although the southern coastal States offer good markets for fish when it is available, the facilities for handling fresh fish are limited, with the result that there are stretches of coast where the mullet is almost unused. If a brine-salted mullet of good quality were prepared and marketed, the food supply of the country would be increased, and an appetizing protein food would become available to low-income groups in the southern States. The method described here is representative of good commercial practice.

Mullet are taken commercially by haul seines, and gill, trammel, pound, and cast nets. The run-around gill net is the most important type of gear accounting for 69 percent of the total catch in 1940. The haul seine is second in importance, credited with 15 percent of the catch.

Splitting, Cleaning, and Washing

Speed in handling is essential to a successful cure. Mullet must be split and cleaned as soon as landed. For a satisfactory product the maximum time allowable after catching is 6 hours. The fish are first rinsed thoroughly in clean salt water to remove slime and sand. The heads of all but the smallest are removed by cutting along the forward edge of the napes, or collarbone, which should be left in. The fish are then split down the back from head to tail, so that they will lay flat in one piece. To avoid a ragged appearance the knife should not cut entirely through the body in the tail section. A cut is made under the backbone also, to aid in penetration of the salt. If the mullet weigh more than a pound and a half each, about three-fifths of the backbone may be cut away, leaving only the tail section in the flesh. On larger mullet, the flesh is scored to a depth of about ½ inch in lines parallel to the backbone. Often both medium- and larger-sized mullet are filleted before salting, especially if they are to be packed in kits or tubs.

After splitting, the mullet are eviscerated. The black membrane lining the belly cavity should be removed. This is best done by scrubbing with a piece of coarse canvas or sacking. Thorough cleaning helps to remove blood and bits of membrane. The fish are then trimmed of any ragged edges, and washed in clean sea water or in a 50° salinometer brine, the latter being preferable. It is also good practice to soak the fish in brine from 30 minutes to an hour to remove diffused blood from the flesh.

Salting

After soaking, the mullet are heaped in a pile flesh side down, to drain for about 10 minutes. The fish are salted in vats holding about 400 pounds, though fountain syrup barrels or tierces may be used. Barrels that have held meat, butter or pickles, are likely to give an "off" flavor to the fish and should not be used. A thin layer of salt is scattered on the bottom of the butt or salting tank. The fish are then taken singly and dredged in salt, rubbing it well into the flesh, especially into the cuts made in the surface. The salt used is of packers-fine or dairy-fine grade. A somewhat coarser salt, three-quarters ground is sometimes used. Some packers use half-ground salt, which is not good, because the coarse crystals puncture the flesh and are slower to dissolve. Fine salt gives better results, although more care and accuracy are required in salting. As a rule, one part of salt should be used to three parts of fish. If the mullet are large and fat, the salt may be increased to about one part of salt to two parts of fish. An excess of salt will "burn" the flesh, giving it an acrid, unpleasant flavor.

The fish are laid in the butts or large barrels, skin-side down. A sprinkling of salt is scattered over each layer. Another layer of fish is laid at right angles to the first. The last layer is packed skin-side up and covered with a heavier layer of salt. The top is usually weighted down to keep the fish covered with the brine or pickle.

Sufficient brine to cover the mullet should form in from 12 to 24 hours. The fish should remain in the brine until they are "struck." This varies from 72 hours for the smaller fish to 10 days for the largest. The average time is a week. In warmer weather the time is reduced. The texture of the flesh determines when the fish are struck; the flesh should feel decidedly firm when pressed between thumb and forefinger, and the depressions should disappear slowly (Jarvis 1945a).

Repacking and Storage

When the mullet are struck they must be repacked. They are taken out of the salting butts, and scrubbed in clear brine to remove slime, undissolved salt, and other debris. They are graded as to size, thickness, and condition, and allowed to drain for one or two hours before packing in the final container. A barrel holding 100 pounds is the standard container for salt mullet, though tubs in sizes holding from 20 to 50 pounds are sometimes used. Mullet fillets are always packed in tubs.

A scattering of salt is thrown on the bottom of the container and the fish are laid in flesh side up, with the thick side against the wall of the container. The mullet must be packed evenly and smoothly. A scattering of salt is thrown over the layer of fish and a second layer is packed at right angles to the first. This is continued until the container is filled, with the last layer packed skin side up. The amount of salt used in repacking should be about 10 pounds to 100 pounds of fish.

When filled, the containers are headed up and fresh 90° to 95° salinometer brine is added through the bunghole, until no more can be absorbed. The bung is then driven in and the barrel placed in chill storage at a temperature of approximately 40° F. Some of the fillets and larger choice fish are repacked in brine tanks in chill storage, and are not packed in the final container until ordered by the retailer. While in storage the containers must be inspected for leaks at regular intervals. Even when the container does not leak, there is loss of brine from absorption by the fish; therefore, brine should be added at regular intervals. Oxidation or rusting will occur if the mullet are exposed above the surface of the brine.

In storage in the southern States at average room temperature, the salt mullet is reported to be at its best in from 1 to 6 weeks after packing; the maximum storage period is less than 6 months. It is believed that mullet should not be used after 3 months of storage at room temperature. The fish held in chill storage remain in excellent condition for a considerably longer period.

SABLEFISH OR BLACK COD

The sablefish or black cod (*Anoplopoma fimbria*) is found from Southern California to Alaska, with the greater part of the catch made off the coasts of Alaska, British Columbia, and Washington. They are caught mostly by long line, incidental to the halibut fishery, though with the development of the Pacific otter trawl fishery, increasing amounts are taken by the latter type of gear. Sablefish are caught all year round but the smallest catches are made when the halibut boats are not operating. Production of salted sablefish has remained at a level of 80,000 to 100,000 pounds annually for the past 20 years.

The sablefish is one of our best food fishes, and makes an excellent brine-salted product. It is one of the richest and fattest of American fishes with a firm, white, flaky flesh which has an appetizing flavor. In spite of its high fat content the salted sablefish does not oxidize readily when properly prepared and handled.

Sablefish are cured as follows:

The head is cut off, retaining the napes (collarbone). A cut is made down the belly to the vent and the fish is eviscerated. Then it is split in two sides, using much the same method as when butchering for mild-cured salmon. Some packers split down the back, leaving the belly whole, as in preparing hard-salt salmon. The backbone, however, is always removed. For convenience in salting and repacking the first method is best for large fish, while the second gives best results with small. Sablefish are washed thoroughly after splitting, then allowed to drain until all surplus moisture is removed.

The sablefish are salted in mild-cure tierces or salting vats. A thin layer of salt is scattered on the bottom. The sides of fish are dredged in mild-cure- or three-quarter ground-salt, then packed in the vat in a level layer, flesh side up. Salt is scattered over the layer of fish until no flesh is exposed. A second layer of fish is then packed at right angles to the first layer followed by a layer of salt. This is continued until all the sablefish are packed in salt with the last layer skin side up. An average of 40 pounds of salt is used per 100 pounds of fish. Because of the fatness of the fish it is necessary to use more salt than with other species. The top of the vat is weighted down and brine is formed as salt extracts moisture from the fish. It requires approximately three weeks for the salt to strike through, a longer time than for most other varieties.

When the sablefish are thoroughly cured they are repacked for shipment. The sides are removed from the salting vat and scrubbed in brine to remove slime, dirt, and excess salt. After the fish have drained sufficiently they are packed in barrels to a net weight of 200 pounds. Repacking follows the same method as for hard-salt salmon or brine-cured cod. A little fresh salt is scattered over each layer, using about 15 pounds to the barrel. The barrel is headed up and it is filled through the bunghole with fresh brine testing 95° to 100° salinometer. Salted sablefish is marketed mostly through the Middle West, where it is a favorite product among Scandinavian-Americans.

HERRING SALTING

SPECIES CURED AND EXTENT OF HERRING FISHERY

Two species of herring are taken in North America. One is found on the Pacific coast (*Clupea pallasii*), the other on the Atlantic coast (*Clupea harengus*). These fish are classified as separate species because of minor anatomical differences, which are indistinguishable to the layman.

The herring are confined to the Sub-Arctic and North Temperate zones. On the Atlantic Coast of North America they range from Cape Hatteras to Labrador, but the commercial fishery does not extend south of New Jersey, and the only really intensive fishery is on the Maine coast in the United States and the provinces of Nova Scotia, New Brunswick, and Newfoundland in Canada. On the European coast the range of the herring extends from northern Norway to the coast of southern France. The most intensive fisheries are off the coast of Norway, Scotland, and in the North Sea. The range of the Pacific herring is from San Diego in the south, to Nome in the Bering Sea, and to Kamchatka and northern Japan in the eastern Pacific. The only important United States herring fishery in the Pacific is on the coast of Alaska. British Columbia also has a very extensive herring fishery.

On a world-wide basis, the herring is the most important preserved fishery-product. The largest amount is preserved by brine-curing, with smoking in second place, and canning, third. In Europe, the greatest production of cured herring is in Norway, with the United Kingdom, Netherlands, Iceland, Sweden, and Denmark next in order. In North America, Newfoundland is the most important producer, followed by Nova Scotia, and Maine. On the Pacific coast, Alaska ranks first in herring curing, with British Columbia second.

DEVELOPMENT OF HERRING CURING

The preparation of brine-cured herring has been an important industry since the early Middle Ages. The first authentic writings dealing with herring-curing date from the twelfth century. Cured herring was one of the principal articles traded on the continent of Europe by England. The herring fisheries were the cause of several wars in the Baltic between some of the Hanseatic cities and various Baltic States claiming grounds fished by the Hanseatic towns. The wars between England and Holland are held to have been caused in general by their rivalry in trade and in the acquisition of colonial possessions, but the immediate cause was a struggle for control of the herring fishery on the East Anglian coast.

The method of herring curing is considered to have been crude until the time of William Beuckels, a fish merchant of Biervliet, in Flanders, who, during the fourteenth century, greatly improved the methods in use. This new development laid the foundation for the great wealth acquired later by the Netherlands from the fish curing business. Beuckels died in 1397, and his work was later considered so valuable that a monument to his memory was erected in his native village by Charles V.

The first mention we have of pickled herring in America is by Josselyn, in the seventeenth century, who, in his Chronological Observations of America, states: "We used to qualify a pickled herring by boiling of him in milk." It is believed, however, that the pickling of herring was carried on by the earliest settlers of America, and possibly by the fishermen who came to these shores from Europe even before the first settlements were made, since the herring were readily caught in shore waters and herring curing was even then the most important fishery industry in Europe.

The first recorded commercial

pack of brine-cured herring on the Pacific Coast of North America was made at Fort Wrangell, Alaska, in 1878. Development of the industry was slow, the pack varying between 2,000 and 4,000 barrels, mostly "bloater stock" (for smoking as bloaters), until World War I, Scotch-cured herring was no longer available in the eastern United States market. It was thought that a herring-curing industry could be developed in Alaska to fill this demand, so in 1918 the Government sent A. H. Klie, an expert herring curer, to Alaska, to introduce the Scotch style of cure. Production rapidly increased to 145,000 barrels in 1922. This is the record pack of brine-cured Alaska herring. The Alaska herring-curing industry is now at a very low level. The pack of 1911 was 4,651 barrels, and the pack of 1944 was reported as 4,159 barrels. This decline was accelerated during World War II, when Alaska became a war zone. It was evident, however, for several years previous. The decline is believed due to several factors, such as overfishing, high labor costs, high freight costs, foreign competition, and the irregular quality of the Alaska pack.

TYPE OF PRODUCT

A number of methods are used in brine-salting herring. It is almost impossible to list or discuss all the types of herring curing, but the six principal methods of brine-salting are: (1) round cure; (2) split cure; (3) Scotch cure; (4) Dutch cure; (5) Norwegian cure; and (6) matje cure. The Scotch cure is the most important commercial process used in the United States. It is a mild cure with limited keeping quality and is not suitable for some purposes because of the flavor given to it by the "blood pickle" employed in curing. Most of the miscellaneous types of brine-salted herring are given a much heavier cure and will, therefore, keep longer. As a rule, the largest herring obtainable are used for salting.

ROUND CURE

This is also known as the bulk cure. It is chiefly used to cure herring intended for smoking or spicing, although it is sometimes employed in preparing bait herring or for curing a few barrels of herring for local sale.

On the Maine coast, the herring may be caught by weirs or seines. The season for large fish taken by weir usually runs from August to about November 15. Seine herring are caught off-shore during the winter months. On the Alaska coast, in the Cook Inlet area, herring given the round cure are taken by gill nets during the winter months.

The fish are rarely if ever cured at sea, although this was formerly customary (Stevenson 1899). When the herring are loaded into the hold a little salt may be scattered on them if it is probable that the fishing boat will not reach port within a few hours, but in winter this is not considered necessary.

When landed, the herring are washed to remove scales, blood, slime, and trash, such as seaweed. Washing may be done by a hose, or in a drum (squirrel-cage) washer. After being drained for a few minutes, the herring are packed in wooden vats or tanks. These vary in size, but a vat 3 feet deep, 3 feet wide, and 10 feet long, is typical. Salt is mixed with the herring as they are placed in the vat. Experience and judgment are needed to determine the proper amount of salt required for curing. The quantity varies according to the size of the fish, their fatness, and condition (according to the length of time out of the water and the probable approach of decomposition), temperature, and humidity. If too much salt is used, the fish will soon become hard and dry and their flavor will be acrid and unpleasant. If the quantity of salt is insufficient, the fish within a short time will become tainted and unfit for food. More salt must be used in warm weather than in cold; fat herring require more than lean, and small herring need less salt than large. As a general rule, from 60 to 80 pounds of salt are used to each barrel (200 pounds net weight) of herring. When the fish are thoroughly mixed with salt, they are also covered with saturated salt brine (100° salinometer) as this ensures more rapid curing.

The herring remain in the vat from 8 to 10 days or until they are struck, that is, until the salt has penetrated their bodies thoroughly. During this time, the fish in the vats are stirred with a wooden paddle to prevent them from sticking together and to ensure an even cure. More salt may be added when stirring, if the brine shows any appreciable decrease in strength. When the herring are cured and are ready for shipping, they are removed by dip net and piled on a packing table to allow them to drain. After several hours of draining they are then packed into barrels to a net weight of 200 pounds. The herring are usually packed on their backs, bellies up, and at a slight slant. The method of filling is much the same as in packing Scotch-cure herring, with each layer laid at right angles to the one preceding. The fish are packed on more of a slant than in the Scotch cure and not so tightly. A little salt is scattered between the fish and over each layer, about 25 pounds to the barrel. The top layer is packed with backs up and receives a little more salt than the others. The filled barrels are headed, a hole is bored in the bung of each, and as much 100° salinometer brine as possible is poured in through a funnel. The barrels are then ready for shipment. The loss of weight in curing round herring is small, ranging from 6 to 10 percent. An average of 211 pounds of fresh herring are required for a 200-pound barrel of cured fish (Jarvis 1943b).

SPLIT CURE

This method is followed in Newfoundland, Nova Scotia, and other coastal areas in eastern Canada, and in New England. It is of minor importance in New England but is an important method of salting herring in Newfoundland. Formerly, only the largest fish were given this cure, but recently, all sizes have been packed as split-cure herring.

They are first soaked in brine for a few minutes to set the scales and to make handling easier. The herring are then split down the belly to the vent. The head is usually left on and, if so, the gills are taken out. The fish are next cleaned and as a rule the milt or roe are removed with the viscera.

After cleaning, the herring are soaked in salt water or light brine for 2 or 3 hours to remove blood and slime. They are then drained for a few minutes and packed in butts or large barrels, backs down, with the belly cavities filled with salt. More salt is scattered over each layer, using from 30 to 40 pounds to each 100 pounds of fish. Split herring require less time to cure than round herring or about 1 week. When thoroughly struck, the fish are repacked in barrels, using the same general method described for round cure. The repacked barrels are headed-up, filled with 100° salinometer brine, and are ready for shipment.

A few barrels of herring are sometimes prepared by a variation of the split-cure. A cut is made across each fish just back of the pectoral fins, removing the head. The cut is continued down the ventral side to the vent, removing most of the thin belly flesh. The kidney (the dark "blood streak" along the backbone) is scraped away, and the fish are thrown into the tank to soak. After an hour or two, the herring are removed and packed directly into barrels, backs down. Some salt is scattered over them as the fish are packed in the layer, and more salt is scattered between each layer. About 30 to 35 pounds of salt, mixed with 2 pounds of fine, white pepper are required to each 100 pounds of fish. After 4 to 6 days, the barrels are filled with additional layers of fish of the same day's cure as those already in the barrels. The barrels are then headed and filled with fresh filtered 100° salinometer brine.

Another variation of the split-cure is occasionally prepared. Only large fat herring are used. The fish are washed in brine, then split down the back to open in one piece, mackerel style, taking care that the knife does not go all the way through the body. The gills, viscera and belly membranes are removed. The cleaned fish are soaked in 50° to 60° salinometer brine for from 1 to 2 hours, then drained and packed in barrels, flesh side up, in the same style as mackerel. An average of 35 pounds of salt is used to each 100 pounds of fish. After about 4 days (when the fish have settled) additional layers of the same day's cure are added. The barrels are headed and filled with fresh 100° salinometer brine through a hole in the bung.

SCOTCH-CURE

In Scotland, herring salting is that country's most important fishery industry. In normal times, Scotland exported more salt herring to the United States than was prepared in this country. The Scotch-cure method is also the principal style of cure employed in Sweden, Canada, and Alaska. A knowledge of methods followed in the Scotch-cure is, therefore, important to fish curers in the United States. The standard reference on the Scotch cure of herring is The Art of Fish-curing, by "Viking" (Duthie 1911), which should be consulted for a more detailed account of the method than it is possible to give here.

The Scotch-cure herring industry is located principally on the Shetland Islands, on the east coast of Scotland at Frazerburgh, Peterhead and Wick, and on the east Anglian coast at Yarmouth and Lowestoft. The herring are taken by "drifters," using a long chain of gill nets. They are taken from areas close inshore to a distance of 80 to 100 miles from shore. The herring are sold in the open market to the curers, using a basket measure known as a "cran."

When the fishermen empty their baskets into the curer's containers, the herring are mixed well and regularly "roused" with salt. The herring are then delivered to the curer's plant where they are held in bins or gibbing-troughs until they are gibbed (gutted). This should always be done as soon as possible. The herring are gutted with a short-bladed knife, removing very little of the fish, only the pectoral fins and upwards to the gills. The gutted herring are thrown into tubs or baskets, one for each size being packed, usually two to four. When sufficient herring accumulate in each tub they are "roused." This is considered the most important step in the Scotch-cure process. A few platefuls of salt are thrown over the gutted herring after which the packer stirs them about in the tub until every herring has come freely in contact with the salt.

When the herring have been thoroughly mixed with salt they are ready for packing. The herring are shaken to free them from surplus salt and a few handfuls are dropped gently into the bottom of a barrel, which is damp inside and has been previously inspected to make sure that it is tight. No salt should be spread in the bottom of the barrel. The method of filling is as described in detail under the discussion of Alaska Scotch-cure herring, except that as a rule somewhat less salt is used in Scotland than in Alaska. Usually the herring are packed above the level of the barrel, as they sink rapidly in the salt. On the following, or second morning the fish will have sunk so that there is some space in the top of the barrel. This should be filled up level with the top, using herring of the same day's cure. The barrel is headed and laid on its side. After the barrels have laid on their sides for 8 or 10 days, a bunghole is bored in the bilge. The barrels are set on end, with the heads taken out and the pickle is allowed to run off through the bunghole.

The barrels are then filled with herring of the same day's cure. A barrel of herring is required to refill five barrels. Very little salt should be scattered between layers and none at all over the top layer. When the barrels have been properly filled, a little clear brine is thrown over the top layer to improve the appearance of the fish (fig. 20). After heading up, the barrels are completely filled with strong brine and the cure is considered complete.

There are two types of grades or brands in Scotland, the Government or "crown" brand and the private or "trade-mark" brands of curers who do not use the Government brand. The reputation of Scotch-cure herring is built on the crown brand, however, and the sizes as determined by the Scotch Fishery Board are representative of the industry. They are, as reported by Duthie (1911):

Lafull Herrings intended for the crown lafull brand must be "large, full fish of not less than 11¼ inches in extreme length" when cured. If on examination, more than fifteen spent, torn, or broken, or more than fifteen undersized herrings are found in the original packing of a barrel, or more than six in the filling up, the inspecting officer is entitled to withhold the brand.

Full For the "full" brand the herrings should be "full fish of not less than 10¼ inches in extreme length when cured". Eighteen objectionable herrings in the original packing and nine in the filling up constitute the limits allowed for this brand. For both the "full" and "lafull" brands the herring should be quite full of milt and roe.

Matfull "Matfull" herrings are 9¼ inches long when cured, but in this case it is sufficient if milt or roe is clearly visible at the neck or throat. If more than twenty-one defective herrings are found on inspection, or more than nine in the filling up, the officer is justified in rejecting the fish.

La Spent For the "la spent" brand, the herrings should be not less than 10¼ inches in extreme length when cured. If more than eighteen obectionable herrings are found in the original packing, or more than nine in the filling up, the fish are not considered worthy of the brand.

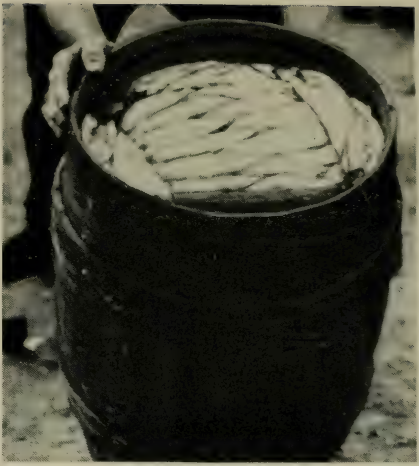

Figure 20.—Scotch-cure herring showing arrangement of fish in the barrel. (Copyright photograph courtesy British Ministry of Food.)

Spent The crown "spent" brand is applied to barrels of "spent" or empty fish of less than 10¼ inches, but not less than 9 inches in extreme length, provided not more than 18 objectionable herrings are found in the original packing, or more than 9 in the filling up.

Mattie The "mattie" brand is put upon barrels of small sized herrings that are ineligible for any of the other brands. They must however, be at least 9 inches long, and the original packing should not contain more than 30 nor the filling up more than 12 torn or otherwise defective fish. To be eligible for this brand, however, fish must not have been caught on the coast of Shetland before the first of July, or on the East Coast of Scotland before July 10; and the presence of an excess of oil in the barrels may also disqualify the herrings for the brand.

ALASKA SCOTCH-CURE METHOD

In the United States the "Scotch-cure" method of salting herring is largely confined to Alaska, and differs in some details from the process as followed in the British Isles. The operational details, construction, sanitation, and other manufacturing factors also show differences. Therefore, it is felt that the Alaska industry merits a detailed discussion, especially of the points that are not the same as in the industry in Scotland.

Condition

Herring intended for Scotch-cure must be strictly fresh and in good condition. They must be as free as possible from "feed" or other materials, causing enzymic spoilage. The herring should not be bruised, crushed, or piled deeply in the hold of the fishing boat. Care should be taken to drain off as much sea water as possible in brailing. If the fish soak in sea water for several hours in the hold of the fishing boat they do not make good Scotch-cure herring. A large quantity of the Alaska herring is unfitted for curing because too much sea water has been included with the fish. No ice should be used on herring intended for this cure and they should be processed immediately on landing. Thin or small-sized fish should not be used.

Gibbing

The knife used in gibbing herring is much like a paring knife, but with a short blade, 2 inches long. It has a 4-inch handle. In Alaska, girls wear canvas gloves while gibbing to guard against cutting the left thumb, and for greater ease in handling fish. Scottish girls merely wrap up the left thumb and work with bare hands. When one sees how slimy and dirty canvas gloves become, the Scottish method seems better.

The use of automatic sorters when unloading is common. In most salteries the gibbers are no longer required to spend considerable time sorting out herring too small for salting. The fish are not washed before salting, for washing spoils herring for Scotch-cure.

In gibbing, the herring is taken by the middle with the left hand, thumb on one side of the head, fingers on the other, leaving the throat clear. The knife is stuck through the gills, just under the gill cover. Then, with the edge of the blade toward the gibber, a sharp twist is given upward and outward. If properly done on fresh herring, the throat and pectoral fins together with the main gut, heart, liver, and gills, will be removed at one time. At first, it requires more than one move to gib herring in this way, but with practice the knack is soon acquired. In drawing out the intestine, it is better to pull outward more than upward; otherwise the herring are apt to be torn, especially if they are fat.

Rousing

When the fish are gibbed, they are thrown into rectangular rousing bins, which are placed back of the gibbers. As they are gibbed, all herring are sorted into sizes that are being packed at the time. These may vary from two to four different grades. Each gibber usually has two bins and when more than two sizes are packed, partitions are placed in the bins. In Scotland, the gibbers work in crews of three but in Alaska they usually work singly, though they may sometimes work in pairs.

Rousing the herring is one of the important points of the Scotch-cure method. In the rousing bins, the fish are mixed thoroughly with a specially manufactured kiln-dried rousing salt. A very coarse salt must never be used for rousing. Plenty of salt should be thrown over the herring, to be worked thoroughly and carefully through them by hand. Every part of the herring should come into contact with the salt as completely as possible. Double-washed California salt is generally used in Alaska. The herring are packed in the barrel immediately after rousing.

Grading

Scotch-cure herring are graded into the following sizes in Alaska:

Size when cured: *Inches*	Full fish	Empty[1] fat fish (Matjes)	Number in Scotch barrel (250 lb.)
Not less than 12¼	Extra large full	Extra large	400–500
Not less than 11¼	Large full	Large	600–650
Not less than 10¼	Full	Medium matties	700–800
Not less than 9¼	Matful	Select	850–1,000

[1] Free of well-developed roe or milt.

Herring shrink an average of one-quarter inch in curing; therefore, an allowance of ¼ inch must be made when grading fresh herring for length before curing (Jarvis 1936a).

If the herring have not been properly roused they will be in poor condition when the barrels are opened for inspection. The fish will be sticking together in the layer and when separated they will be scaleless and discolored. Some "rusting" or oxidation indicated by a brown gum or deposit adhering to the skin will have occurred. In this connection it is important that the herring be packed as soon as possible after rousing. If this is not done, some of the original pickle will form in the rousing bin and will be lost. Fish not properly roused are usually too hard-cured and do not have the desired flavor or texture.

The standard Scotch-cure herring barrel holds 250 pounds, net weight of herring, is made of spruce staves ¾ inch thick, is 30 inches high, has a 17-inch head, and a capacity of 32 U. S. gallons (26⅔ Imperial gal.). The largest portion of the Scotch-cure herring packed in Alaska, however, is put up in half barrels holding 125 pounds, net weight, of fish. All barrels should be new, of best quality, should be inspected carefully by the cooper for leaks or any other possible defects, and soaked before use.

Packing

Herring intended for Scotch cure are never washed before being gutted and salted, either with water or brine, and are never repacked. They are cured in the original barrel and in their own blood pickle. No salt is sprinkled in the bottom of the barrel when packing or "laying" herring. If the fish have been properly roused, enough salt will cling to the bodies. Care should be taken when lifting the herring from the rousing bin not to carry any of the loose or surplus salt into the barrel as this makes for a non-uniform salting and packing. Some curers shake the fish gently when lifting them from the rousing bin to get rid of surplus salt.

The packer begins by taking one roused herring and placing it, back down, against the side of the barrel, straight up, not at a slant. Two other herring are placed against the first, their heads to the side of the barrel and their tails meeting, or overlapping. A middle herring is placed in front of the tails of the last two, then, two others, one to the right, the other to the left, with heads pointing against the barrel staves, and so on, until the layer is completed. The position of the middle herring is alternated so that the head of the first points to the right while the second middle herring faces the left (fig. 20). Particular attention must be paid to keeping the herring lined straight-up, packed tightly, and the rows regular. If the herring are packed on a slant, with the rows irregular, the curing will be uneven, as one side of the herring will get more salt than the other. The space at the side of the barrel caused by the meeting of the heads of the herring must be filled by placing two herring over the heads of those making the hollow. These two fish, known as head herring, are placed so that their heads point in opposite directions. This leaves an even surface for each of the succeeding tiers.

Salt is then sprinkled over the entire layer. The amount depends on the season of the year, the market for which the fish are cured, and the quality and size of the herring. Duthie (1911) states that as a general rule 1 barrel of salt is required to cure 3 barrels of herring.

A safe rule to follow is to never entirely cover the bellies of the fish of each tier, but give them enough salt to almost cover the bellies, with the exception of extra large herring, especially those with milt and roe which require more salt. Scotch-cured herring when *thoroughly cured* (say after the 14th day) should be free of undissolved salt. Remember that large herring require more salt than small ones, fat herring more than those of poorer quality, milt or roe fish more than empty fat ones of *matje quality.* (Slinks or spents do not come under the matje selection.) Milt herring require more salt than roe fish and remain softer than spawn herring. When the first tier has been packed and salted, continue to pack the second tier *by crossing the first tier at right angles*, keeping the fish belly up. Prevent the lines from curving as this spoils the appearance of the pack. Salt as before and continue packing, salting and crossing each tier until the barrel is full. A little more salt may be added to the tier in the center of the barrel as this helps to keep up the strength of the pickle. (Klie 1920).

Curing

Some packers allow the brine to be formed solely from the moisture extracted from the fish with the added salt, while others add brine. Klie (1920) states that brine should be added in warm weather as it strikes in from both the outside and inside of the fish more quickly than if the brine were left to be formed from the fish, thus reducing any possibility of spoilage. The barrels are usually headed immediately after packing, laid on their sides, and filled with 100° salinometer (saturated) brine through a hole bored in the bilge.

The barrels should always be stored on their sides as the herring cure better in this position, because it allows the salt and brine to strike through the fish more evenly and freely. For the same reason, all barrels should be rolled half-way around occasionally. At this stage, the herring are said to be "in sea stick." From 10 to 14 days are required to cure the herring thoroughly but the barrels are usually refilled sooner.

Refilling

When the barrels are to be refilled they are set on end, the heads are taken off, and the brine or pickle is allowed to run out through the bunghole. The brine is sometimes saved for rouse. The herring will have sunk considerably in the barrel, which must now be filled up. One barrel of herring to every five is required in refilling. The herring used for refilling should be of the same lot as the barrels to be refilled and they should be well washed in fresh, clean brine.

The herring are filled in as described for the original packing but must be handled more slowly and carefully. The usual way is to straighten out each herring between the thumb and forefinger. This not only straightens the fish but also flattens out the belly. Very little salt is added between each layer and none is used on top.

The top layer must present a very attractive appearance as the pack is judged a good deal by the condition of this layer. The bellies of the herring in the top layer must be well flattened out and the fish set straight up on their backs. To get a full barrel, the herring must show above the croze. When the top layer is completed, the heads are pressed down on each side of the barrel, and three head herring are laid in on each side to make the layer even. These must also be packed straight up with backs down. The head of the barrel is then "jumped in." This usually requires considerable pressure but flattens out the herring on top and leaves no space which would allow the fish to shake about in transportation. This practice is not followed in packing summer herring. The barrel is laid on its side to be filled with brine testing 80° to 100° salinometer. This may be the original pickle, which has been strained, or fresh pickle may be used. The bung is then driven in and the cure is complete.

Branding

When the head of the container is dry, it is stenciled with the name of the packer, trade mark or brand name, grade, and place of cure. According to law the approximate net weight of the herring must be marked on each container. This is usually stamped on the bottom end, 250 pounds net, for barrels, and 125 pounds net for half barrels. A few packers also mark the gross and tare. This practice is not followed regularly.

Transportation and Storage

The cured herring are moved out of the saltery warehouse as soon as possible and shipped to Seattle, the primary marketing center, by steamship. In shipping, the barrels must be stowed carefully and must be kept away from boilers or steam pipes. On landing, the herring are unloaded into warehouses, where they are held in chill storage at 34° to 36° F. until sold. They must be kept in chill storage, as they are mild-cured; depending, in part, for flavor on the "blood pickle," which ferments and sours easily at higher temperatures.

DUTCH-CURE HERRING

Herring are usually caught in drift nets (gill nets) a considerable distance out to sea in the Netherlands. Whenever possible the gibbing is done as the nets are hauled on board and the herring are picked out. The Netherlands way of gibbing and cutting is very little different from the Scotch, except that no attempt is made to pull out the crown gut, as it is believed that too much of the fat which gives the fish a nice flavor is removed at the same time. The opening at the throat is also a little smaller than for Scotch cure herring.

As the herring are dressed they are sorted into baskets according to size. When there are about 200 herring in a basket it is dumped into a large tray or shallow box filled with fine Lisbon salt. The gutted fish are mixed or roused thoroughly with the salt, which, in this instance, is called "dredging" or "rolling."

When the herring have been rolled sufficiently in salt they are packed in barrels, backs down, using the same method as for Scotch-cure herring. A little Lisbon salt is thrown between each layer. The amount of salt used, as a rule, is slightly less than for Scotch-cure herring. When the barrels have been filled, a bucket of "blood pickle" is poured into each barrel. This pickle is a brine made from the gibs and blood removed in dressing. These are saved and mixed together with sea water and salt to make the pickle. After adding the pickle the barrels are headed up at once and stored in the hold of the fishing vessel.

The barrels are headed at once so that the herring will be affected by air as little as possible. The barrels are left in the hold for from 6 to 10 days, when the herring should be struck through. The barrels are taken on deck again, the brine is drawn off, and the barrels are filled with herring of the same day's pack. The original brine is strained and put back in the barrels. One barrel in four is lost in this filling or sea-packing, as the Netherlanders pack compactly. In this cure it is considered important not to do this filling too early, lest the herring be shriveled, but if delayed too long, the herring will be battered about, injuring their appearance.

When the fishing boats return to port, the heads are taken off the barrels, and the brine is drawn off. The barrels are refilled with herring in final preparation for shipment. In this last filling it is estimated that 14 barrels of herring as landed will give 13 barrels ready for shipment. The filled barrels are headed and "tightened," after which the original pickle is poured in through the bunghole. At this time a great deal of the herring is selected or graded and repacked in kegs of various sizes. A small keg, one-sixteenth of a barrel, holding from 45 to 50 herring, is a favorite size, especially for the American market. Another small keg holding about 12 herring is packed for the American trade. This last size is known in the American delicatessen trade as "milker" herring. A Dutch barrel of full selected herring with milt and roe holds about 800 fish, and weighs from 110 to 115 kilograms net (242.2 to 254.6 lbs.), exclusive of salt and brine. Some selected herring are also packed in Scotch barrels.

Dutch-cure herring are graded first, according to the degree of spawning development, into four grades: Full herring (vol herring, with barrels branded "VOL"); matties (maatjis, branded "M"); spent herring (ijlen, branded "IJ"); and herring which have recently spawned (ruit, branded "KZ"). Each of these grades is further divided for quality into three subgrades. The barrels are marked 1, 2, or 3 according to grade. For example, a barrel of first-class full herring would be marked "VOL 1." Herring cured the same day when caught, in good condition and free from faults, are graded as 1 or 2 according to quality and treatment. Herring which could not be packed the same day when caught (because of a large catch) but were cured the next day, together with chafed fish, or herring with torn bellies, are graded as number 3. Sometimes barrels holding herring not packed the same day when caught are marked "O." Dutch-cure herring packed in Scotch barrels are graded as follows: Superior, 600 to 650 herring to a barrel; Sortierte, 700 to 750; Prima, 800 to 850; and Small full, 900 to 1,000. The Netherlanders also distinguish between the quality of fish caught out at sea or near the coast, and the barrels are generally marked to show this.

NORWEGIAN-CURE HERRING

In Norway the greater proportion of the herring catch is made in the fjords by a large seine known as a "landvade." When a school is found, one end of the net is fastened on shore while the remainder is used to surround the fish. The seine is gradually drawn in until the fish can be pocketed behind the net in a cove or under the lee of a headland. The herring usually are held in the pocket at least 24 hours because they are often full of feed when caught. After 24 hours the digestive tract is empty and the herring are not so susceptible to enzymic deterioration on the way to the saltery and during the first stages of the curing process. The fish are usually cured in the vicinity of the place where they are caught, so they can be put in cure when almost alive. This gives the Norwegian-cure herring an advantage in quality over the Scotch- and Dutch-cure herring. The herring may be held in the nets for weeks if necessary, removing at one time only enough for the daily curing requirements.

When the herring are brought ashore the first step in preparation is gibbing. As seine-caught herring are mixed in size each gibber has from three to five tubs, one for each size being packed, into which the herring are sorted as they are gibbed. Although the herring can be gibbed for the Norwegian cure with the fingers or a small knife, as a rule a specially developed scissors is used. Only a small cut is made at the throat, much smaller than for the Scotch cure. The fish are bled rather than gutted. A small triangular piece including the pectoral fins is removed, just large enough to include the heart. The cut must be deep enough to cut into the main blood vessels, close to the neckbone, in order to remove the blood they contain. The gills are not removed except from full or spawning herring. The sizes into which the herring are sorted, with the grade marks, are as follows:

Grade mark	*Size of fish when cured (inches)*	*Number of fish in 100-kg. barrel*
KKKK	Not less than 12¼	425–475
KKK	Not less than 11¼	550–600
KK	Not less than 10½	700–800
K	Not less than 9½	800–900
M	Not less than 9½	(1)

[1] More than 900.

No salt is thrown in the tubs with the gibbed herring. After sufficient fish of any one size have been gibbed to make it worth while to handle, a salter packs them in new barrels that have been well soaked in sea water. A scattering of salt is thrown on the bottom. The herring are then laid in, packed on their backs, slantwise, one fish lying across the other throughout the layer. This is in contrast to the Scotch method where the fish are packed straight up, on their backs. The Norwegian-cure fish are also packed much more loosely than the Scotch. The method of arranging the layers in the container is otherwise much the same. As the herring are packed in, salt is scattered between them in the layers, and a thin layer of salt is scattered between layers of fish, using a total of about one-third as much salt as fish. The uppermost layers are often packed in, backs up.

Some packers add two gallons of saturated salt brine to each container as soon as it is filled and head the barrel immediately. Others do not add brine or head the barrels until one day after packing. Before the barrels are headed, a layer or two of herring are generally put into them, in order to fill the space created by the shrinkage of the herring. If the brine is added immediately after packing it is believed that the salt dissolves more quickly, hastening the rate of penetration through the fish. The barrels are allowed to stand from 10 to 14 days after heading. At the end of this time they should be completely cured and ready for repacking.

In repacking, the first step is to remove each barrel head and drain off some of the "pickle," which is saved. The fish are not taken out of the barrels in repacking. This consists of adding additional layers, backs up, in the top, filling the space created by shrinkage of the fish in curing and by draining off the brine. The method of fill is the same as in the original salting. Fish of the same day's cure is used for repacking and a little salt is scattered between each layer of fish. In repacking, 4 barrels of the original cure are required for 3¼ to 3½ barrels of the finished cure, or a loss of 18.8 to 22.5 percent. The filled, repacked barrels are headed immediately and filled with strong brine. The original brine or pickle drained off for refilling is usually strained and used again. If there is not enough of the original brine, fresh brine is made and added. The Norwegian barrel is one Imperial gallon smaller than the Scotch barrel in capacity. While the Norwegian-cure herring is more heavily salted than the Scotch-cure, the difference is not so marked as it was. Also in contrast to the Scotch-cure, these herring contain more fat than milt or roe.

MATJE CURE HERRING

The matje cure is a very mild cure applied to empty fat fish, that is, fish not in spawning condition. The stomachs are usually full of feed, composed of small shrimp-like organisms. Some matje cure herring have been packed in Alaska, but the complaint is made in New York and other Atlantic coast areas that this pack is too heavily cured. The best matje-cure fish come from the Hebrides, followed by those from the Shetland Isles, off the coast of Scotland. The following description outlines Scottish practice in preparing the matje cure. The herring require careful curing, begun as soon as possible after catching. The fish should not be left exposed to the sun while awaiting cure and they must be handled as little and as carefully as possible. If the herring are weighted down or handled at all roughly, they become bruised and softened, making them unfit for the cure. Gutting must be done very carefully and thoroughly, otherwise the stomach contents and fat adhering to the crown gut may cause rapid deterioration.

As a rule, two sizes of herring are selected, large and medium. Small, torn, or broken fish are discarded. English second fishery-salt (equivalent to the three-quarter-ground salt of the Pacific coast) is used for rousing, and Spanish salt is scattered between the layers. The roused fish are shaken to rid them of surplus salt and the amount of salt added to the barrels is about half the usual quantity for the Scotch-cure. The rousing tubs must be emptied frequently to get rid of the used salt and keep the herring clean. Rousing tubs should have several holes bored in the bottom to allow the blood to escape.

Immediately after a barrel is filled, a fresh, clear, "made" brine testing about 90° salinometer, should be poured into the top, about a water bucket to a full barrel, half that quantity to a half-barrel. The barrels should then be stood on end in a shady curing-shed. After standing for two nights the containers are refilled. The surplus pickle is usually poured off over the rim of the barrel; not through the bunghole. The barrels are not filled quite so tightly as for the ordinary Scotch cure, and while there is usually a certain tolerance for fish that do not meet the grade, in the matje cure all herring that are in the least objectionable should be discarded. When the barrels have been refilled they are headed immediately, filled with brine through the bunghole and stored in a cool, dry shed.

As far as the United States is concerned, chill storage is essential to handling matje cure successfully. As soon as the herring barrels are refilled they should be put in storage at 34° to 36° F. The fish should be held continuously in refrigeration until shipped to the retail market.

SALMON SALTING

MILD CURE

Mild-cured salmon is a lightly salted product which is largely dependent on refrigeration for preservation. The method of curing was first introduced on the Pacific coast in 1889 (Cobb 1930) when a shipment was prepared for the German market, but the experiment was unsuccessful. Salmon was not mild-cured in any quantity until 1898, when two small plants were established on the Columbia River. Packing of mild-cured salmon began on Puget Sound in 1901. While a few tierces were occasionally packed in Alaska prior to 1906, it was not until that year that mild-curing was established on a commercial basis. A large part of the king salmon taken in southeastern Alaska is now mild-cured.

Mild-cured salmon must be considered an intermediate or half-finished product since a large proportion of the amount cured is used to make smoked salmon. Some of the pack was formerly sent to Germany and the Scandinavian countries for this purpose. Two world wars have disrupted foreign trade but meanwhile markets in New York, Philadelphia, Chicago, and other large cities, have absorbed a considerable quantity of the pack.

Mild-cured salmon must be handled more carefully than any other salmon product. In few other food products is handling so important in determining the quality of the finished article. Red-fleshed king salmon (*Oncorhynchus tschawytscha*) is used almost exclusively and dressed fish weighing 18 to 20 pounds are usually regarded as the smallest sizes suitable for mild-curing. There is some variation in this minimum, as at Astoria, Oregon, fish of less than 30 pounds in weight are usually rejected by mild-curers, while in Vancouver, British Columbia, Canada, the minimum size is 18 pounds, dressed weight. From time to time, packs of mild-cured chum and pink salmon have been put up, but have not found a market. Coho or silver salmon (*O. kisutch*), is the only other species utilized to any extent for the manufacture of mild-cured salmon and is usually prepared to fill market demands for a lower-priced smoked salmon. In 1944, according to the Pacific Fisherman, 1,050 tierces of silver salmon were packed in North America. Tierces average 825 pounds net weight of fish, exclusive of brine.

Salmon intended for mild-curing must meet certain requirements as to quality: Fish must be (1) strictly fresh; (2) reasonably fat; and in good condition (thin fish are not wanted); (3) the skin must be bright, there must be no "watermarks" or other blemishes; (4) the flesh must not be pale in color; (5) the flesh must not be bruised or broken and there must be no pew marks or other signs of rough handling; and (6) they must not be belly-burnt, that is, show signs of softening in the abdominal region (Jarvis 1936b).

For this reason troll-caught salmon intended for mild-curing are always gutted when caught and packed in crushed ice aboard ship. Salmon taken by other gear are often gutted, or at least, packed three or four together in a box filled with crushed ice, which acts as a refrigerant, and aids in drawing out the blood. The boxes may be piled up in several tiers in the hold of the boat but the weight is distributed, and individual fish are not weighted down more heavily than by the other fish in the box.

Butchering

The first step in preparing mild-cured salmon is known as butchering. The butcher removes the head, cutting from the back, leaving as much as possible of the bony structure just above and below the gills. This makes the fish stand up better under handling. If the bony structure were cut away, the sides would break easily in curing, and the hooks on which the fish are hung during smoking would be more likely to tear out.

The fish is then scored with three or four cuts along the lateral line. These are made just through the skin, but should not penetrate into the red meat. Scoring allows the salt to penetrate more rapidly, insuring a better cure. A specially designed star-pointed wheel is sometimes used for this purpose. It makes a series of small cuts varying from half an inch in length at the tail, to one and one-half inches at the shoulder. A number of extra cuts or scores are made if the salmon is large. After scoring, if the fish is not already gutted, it is split down the belly to the vent. The viscera are removed, as are most of the belly membranes, and a cut is made along either side of the kidney, the dark red mass found just below the backbone, at the top of the belly cavity. The kidney is then scraped away as completely as possible.

After cleaning, the salmon is ready for the splitter, who is the most important workman in a mild-curing establishment. The grading of mild-cured salmon and the percentage of loss of raw material, depend largely on the skill of the splitter. An unskilled or careless workman is often responsible for considerable losses. A specially shaped knife is sometimes used in splitting, the end of the blade being nearly square, but the type of knife used depends on the preference of the splitter. The splitter turns the fish on its side, nape to his right and with the open belly toward him, and then forces the shoulder down on a sharp-pointed nail protruding from the table so that the fish will not slip. He first makes a cross cut at the root of the tail, but no farther. Short incisions are then made below the anal fin, cutting just above and below the backbone. Then, with the upper "lug" or shoulder tip of the fish in his left hand, the splitter enters his knife at the shoulder above the backbone, and holding the blade steady with the edge at a slight downward angle touching the bone, takes the whole side off with one sweep of the knife (fig. 21). This can be done better if the fins are taken off before gutting. In some plants the fins are removed. If the work has been well done, little flesh will be left on the backbone and the sides will be smooth. A thin line of bone will show down the center of the side, which increases the value of the finished product.

To cut the second half loose from the backbone, a cut is made at the shoulder just under the bone. With one sweep of the knife, the edge of the blade resting against the bone at a slight upward angle, the splitter separates the backbone from the flesh down to the root of the tail, without removing the fish from the nail. As with the first half, little flesh should be left adhering to the bone and a film of bone should show down the center. In other words, the two sides should be exactly alike.

Washing, Trimming, and Chilling

The sides are washed thoroughly in cold water and then passed onto the sliming table where they are laid skin side down with the thin, or belly edge, toward the front. All blood clots, loose membranes, and fragments of bone are removed. Any blood remaining in the veins along the abdominal cavity is scraped off by pressing it toward the back of the fish either with the fingers or the back of a knife blade.

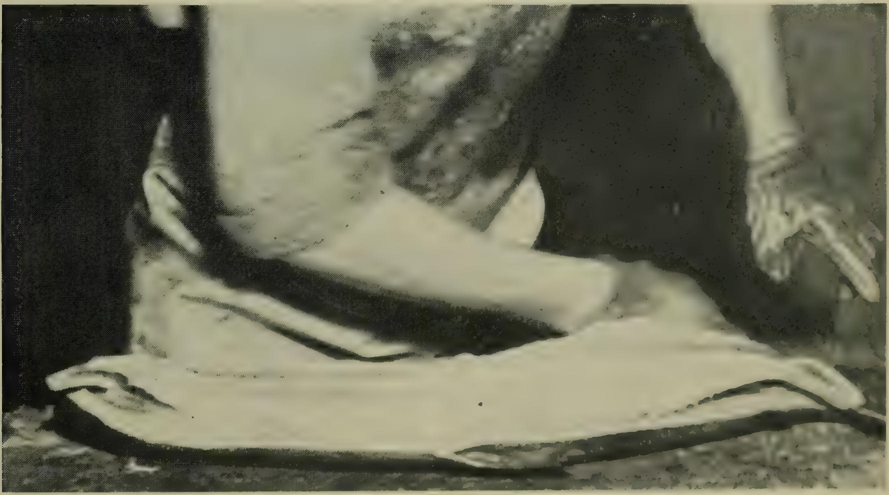

Figure 21.—Splitting salmon for mild cure. (Copyright photograph courtesy *Pacific Fisherman*.)

If the blood is not squeezed out in this way the salt will harden it during the process of curing, causing discoloration of the flesh and lowering of the value of the salmon. Any slight necessary trimming may also be done at this time (fig. 22). Great care must be taken in handling the newly split sides, as they are very tender and may be easily broken or bruised. In lifting them by the lug or collarbone, the curer should have his fingers to the inside and his thumb to the skin side, as otherwise the flesh may be broken.

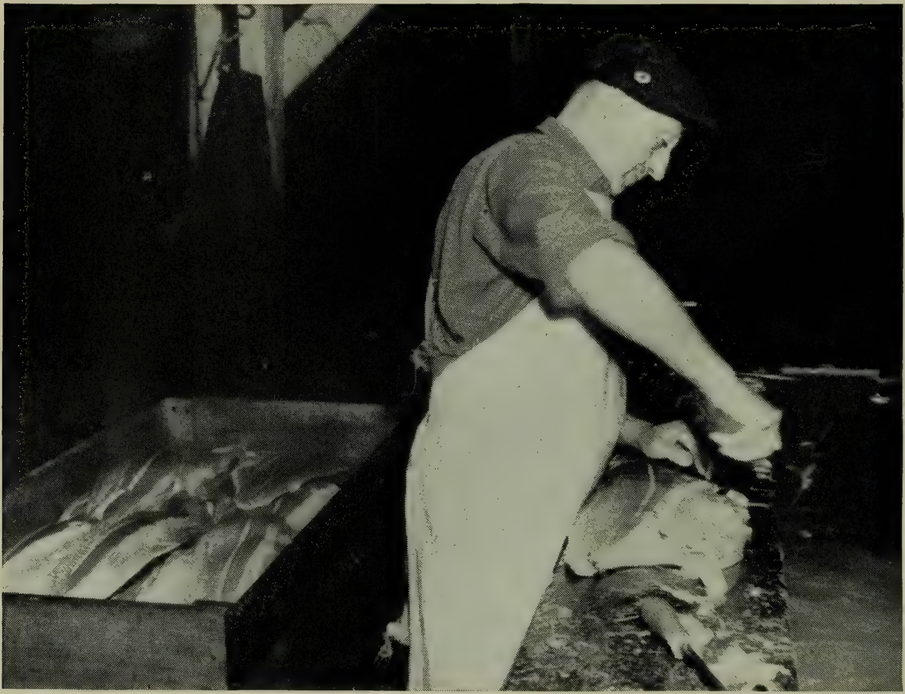

Figure 22.—Trimming split salmon for mild cure. (Copyright photograph courtesy *Pacific Fisherman.*)

From the slimers the sides are taken to a tank of ice-water or iced brine. Warm water tends to loosen up the muscle flakes if the salmon is left too long. This tank is known as the chilling or, more commonly, the sliming tank. The latter name is a misnomer as all slime should be removed before the sides go into this tank. The object of this step is to prepare the sides for curing and it may be likened to case hardening. Unchilled sides would absorb too much brine and the penetration would be too rapid during the first part of the cure. Chilling also serves to draw out the blood, improving the color, and also helps to prevent oil from oozing out of the flesh, which is apt to occur where an amount of cut surface is exposed, especially under pressure during curing. There is some variation in the length of time the sides are left in the sliming tank. In some localities, the period is two hours; in others from one-half hour to one hour. The temperature of the brine may vary from 30° to 40° F. and its salinity from 60° to 70° salinometer. The brine should be made with fresh drinking water, boiled and strained before use, and should be changed at least daily.

After sliming, the sides are drained. This is done in another tank, or the salmon may be placed on a two-wheeled cart or portable table. The fish are transported more easily and it is claimed that the water drains off better where the second method is used. On the Columbia River, a cart holds just a tierceful of sides, 7 lengthwise of the cart, and 3 at the end, or 10 sides to a layer. This arrangement helps in counting the number of sides going into a tierce.

Salting and Packing

When the salmon sides have been drained sufficiently, they are taken to the salter, who works from a special bin or box of convenient height filled with fine salt of the "dairy" type. A special grade of salt known as "mild-cure" is usually demanded, which meets the requirements of a low content of chemicals other than sodium chloride, contains no organic impurities, and is of small, even grain. The salmon is taken one piece at a time and placed in the salt box, skin side down. Salt is scooped over the side with the hands but it must not be rubbed or pressed into the flesh of the fish, as this might injure the texture and cause absorption of more salt than is necessary (fig. 23). Sufficient salt always adheres to the surface by this method. The sides are picked up by the tips, and excess salt is allowed to fall back into the box. They are then packed in a container known as a tierce (Scofield 1925).

A tierce is a large barrel, made from fir or spruce and bound by 6 galvanized iron hoops. It holds between 800 and 900 pounds of fish, with the average around 825 pounds, cured weight. The gross weight, including pickle, ranges between 1,100 and 1,200 pounds. A few handfuls of salt are thrown on the bottom of the tierce, followed by a layer of salmon sides, skin side down. In packing, two sides of fish are laid close to opposite sides of the tierce, alternating head and tail, the back or thick part of each side being placed against the side of the tierce. Other sides of salmon are packed from the sides of the tierce toward the center, napes and tails alternately, the back of each side being drawn half-way up and resting on the side already laid. When complete, the layer should show a level surface, this depending a good deal on how the last or center piece is laid (fig. 24). A little salt is scattered over each layer, which should be laid at right angles to the one preceding. The top layer should be packed skin side up, and a little more salt should be scattered on this layer than on the others. The amount of salt used varies from 85 to 120 pounds to the tierce. One of the leading Canadian mild-curers uses 90 pounds of salt to the

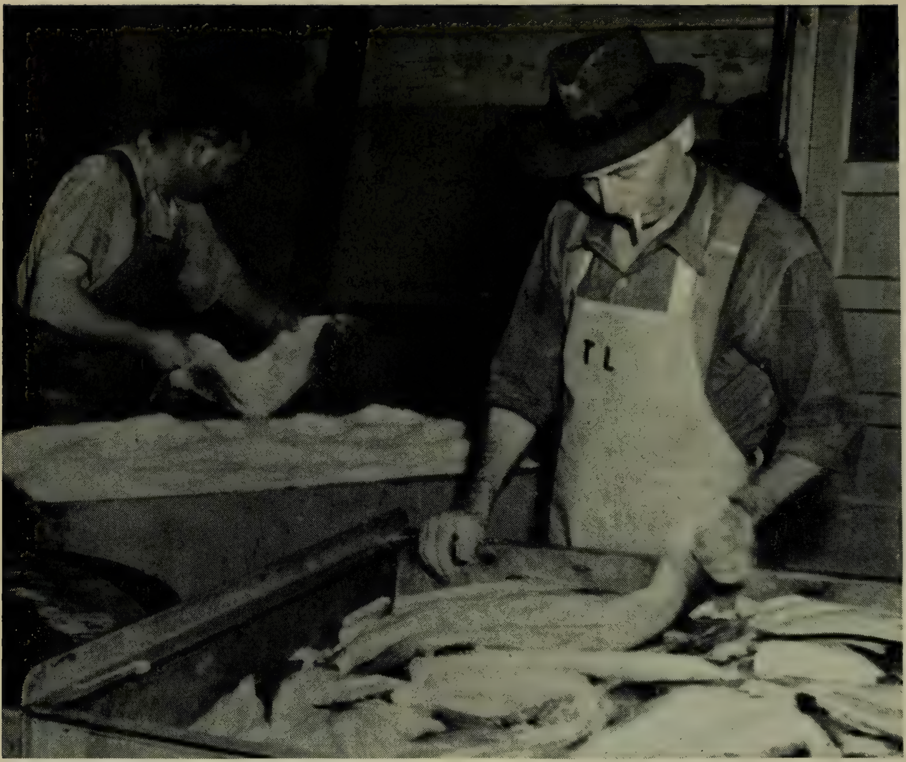

Figure 23.—Salting salmon for mild cure. (Copyright photograph courtesy *Pacific Fisherman*.)

tierce, and this may be taken as the average. Some curers use as much as 15 pounds of salt per 100 pounds of fish.

There is some variation in the curing process at this stage. The tierce is filled only to the croze and in some districts it is headed at once and filled with a 90° to 95° salinometer brine until the tierce will hold no more. In others, the tierce is held from 24 to 48 hours before heading, after which it is headed and filled with 100° salinometer brine. The pickle or brine should be made from the same salt used for rousing and packing the fish. The water used in making the brine should be clear and pure, in fact, drinking water. Before using, the pickle should be strained through a fine sieve or a piece of clean cheese cloth, to free it from any froth, dirt, or sediment. The strength of the brine is then determined by a salinometer. A centigrade scale salinometer is used by most mild-curers. The brine is usually made up to a strength of 90° salinometer, but during the first week or 10 days of the cure while moisture is being extracted, it decreases in strength to about 70° salinometer. After repacking, the strength of the brine should not fall below 85° salinometer, and it should hold this strength for some time.

After the tierces have been headed and filled with pickle, they are usually rolled into a room where the temperature can be kept down to 32° to 34° F. Here they are left to cure, stored in rows one or two tierces high. The temperature of the storage room should be held constant and not allowed to fluctuate, as this causes the oil to exude from the flesh, escaping into the brine. The tierces are not always rolled into the chill room immediately after packing. Some curers, especially those working in cooler climates, leave the tierces in the packing room for 4 days, then send them to the chill room for 10 to 20 days before repacking.

If the tierces are not kept full of pickle, the sides of fish may be shaken about and broken when the tierces are shifted while being inspected, at intervals, to determine whether there are any leaks in the containers. No tierce is perfectly tight at first, and the staves absorb some brine. If any part of the fish is left uncovered by the brine, yellow, discolored spots develop, so-called "rust spots," which lower the quality of the finished product. Therefore, it is extremely important to see that the tierces are kept full of brine during the curing period and also after repacking. A tierce of salmon may absorb several gal-

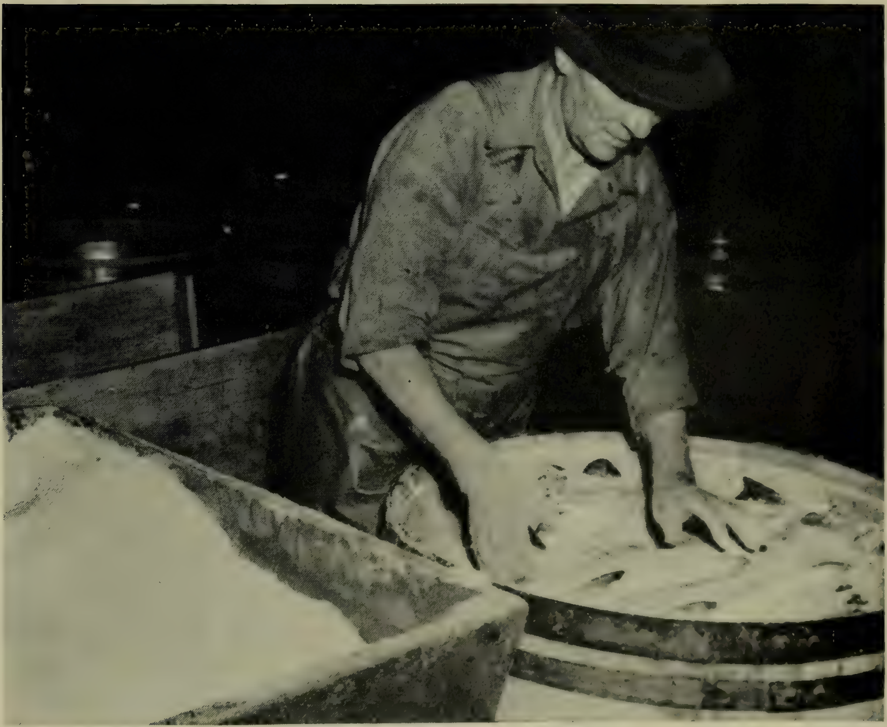

Figure 24.—Packing sides of mild-cure salmon in tierce after salting. (Copyright photograph courtesy *Pacific Fisherman*.)

lons of pickle in the first 2 or 3 weeks of cure, especially if the fish are "dry."

The amount of shrinkage during the first 3 weeks, before repacking, is estimated to be about 30 percent. Less shrinkage occurs in fat ocean-caught fish. Thin "dry" fish, especially those caught when well on their way to the spawning ground, may shrink as much as 35 percent in weight.

Repacking

After the salmon have been held in storage at least 20 but not more than 90 days, they are repacked. The tierces are rolled out and unheaded. Each piece is taken out carefully, holding the sides with the fingers on the flesh side and the thumb on the outer or skin side. The sides are sponged or cleaned carefully, removing all salt or other extraneous material on the surface. Either ice water or chilled brine is used to wash the sides of salmon, depending on condition. If the fish are soft and rather poor (thin), they should be washed in brine, but if the sides are firm and thick, ice water may be used. It is the opinion of some curers that chilled brine should always be used.

The next step is weighing and grading the sides. Unlike curers in other districts, those on the Columbia River grade twice. While the fish are being dressed three chilling tanks are used, one for each size. A rough grading into large, medium, and small sides is thus obtained. This is an advantage in packing and curing, as the time required for curing varies with the size of the side; much work is also saved in sorting for repacking. When repacking, a careful separation is made into from 6 to 10 grades (fig. 25). The designations of the grades depend on the number of sides needed to fill a tierce, and are expressed as 40 to 50, 50 to 60, 60 to 80, 80 to 100, and 100 to 120 sides per tierce. Slightly broken sides are graded as "B" of that size, while other more defective sides are placed in a third grade and called culls. Color of the sides is also considered in grading, and pale or off-color sides are segregated. The system of grading differs somewhat in various districts but this description indicates the general method.

In repacking, the sides of fish should be replaced as nearly as possible in their original position, those curved in shape being placed against the sides of the container, and straight pieces laid in the middle of the layer. No salt is used in repacking but as soon as the tierce is filled, the head put in, and an examination made to determine the tightness of the container, it is laid on the side opposite the bung, and filled with ice cold pickle made to a strength of 90° to 95° salinometer. The tierce will contain about 825 pounds of salmon after repacking, and some 14 gallons (U. S.) of brine may be required to fill it. The gross weight will average 1,100 pounds. The tierce is then put back into chill storage and filled up daily for a week or more with pickle through the bunghole. If mild-cured salmon is stored for any length of time,

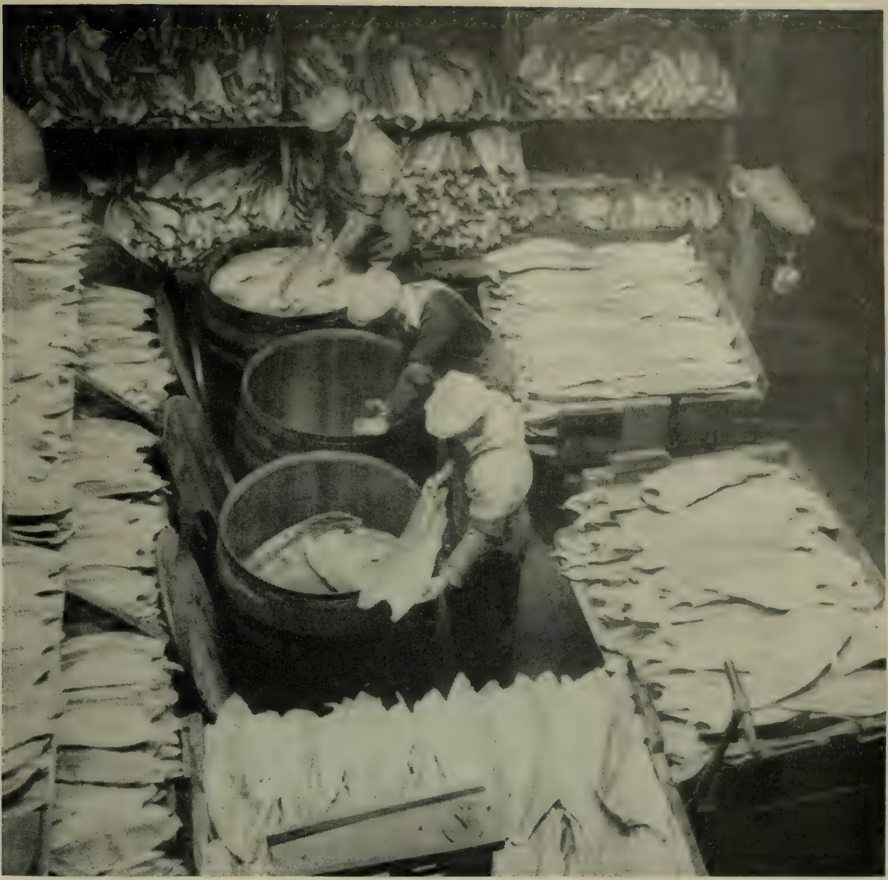

Figure 25.—Grading and repacking mild-cure salmon. (Copyright photograph courtesy *Pacific Fisherman*.)

the tierces must be tested at frequent intervals for leakage.

The head of each tierce is marked to show the number of the tierce (consecutively); the number of salmon sides in the tierce; the net weight, and the initial or brand of the packer. In some districts the tierce is marked with the packer's brand or initials, place where packed, number of sides of salmon in tierce, tare, gross and net weights, quality of fish (I, II, and III or T) and size of fish, L (large), M (medium), or S (small). In Vancouver, British Columbia, thin or broken sides are designated by the letter "X". If the salmon is of first quality no special mark is necessary, but second and third quality fish are always designated.

Storage and Use of Preservatives

Mild-cure salmon must be shipped under refrigeration and held in cold storage at all times. It is held at a temperature of 32° to 34° F., after repacking. If the salmon is to be kept more than three months some packers hold it at a temperature of 28° F. The temperature of storage must not be low enough to freeze the fish. The tierces must be inspected at least once a month, preferably every other week, while in storage. The smoker should leave the mild-cure salmon in storage until the day it is required for smoking. If the smoker must hold some stocks of mild-cure salmon in the smoking plant for longer than a few days, he should be supplied with storage facilities at temperatures not more than 40° F. The salt cure is not of sufficient strength to delay spoilage for more than a brief period.

In the earliest days of the mild-cure salmon industry attempts were made to reduce or eliminate refrigeration by adding various preservatives when curing the fish. These were usually preparations of salicylic or boric acid, and the benzoates or other chemical compounds such as Urotropin, now limited in use or prohibited by food and drug administrations, here and abroad. The use of these agents was soon abandoned, in most cases before they were legally controlled, as it was found that the quality was adversely affected, and was causing mild-cured salmon to become unfavorably regarded by salmon smokers.

SALMON, PICKLED OR HARD-SALTED

Production, Species Salted, Gear Used

Pickling or brine-salting was the earliest commercial method for the utilization of salmon. The trade first became important in the early eighteenth century. Under conditions of transportation and methods of food handling of that time only a salted product could reach London from the Scottish and Irish salmon fisheries. At almost the same time the salmon of the Atlantic coast of North America were brine-salted, some for export to England, the rest for local sale. At one time, salmon were salted as far south as the Hudson River. A small amount of salmon (*Salmo salar*) is still salted on the Atlantic coast of North America in Nova Scotia, Newfoundland, Labrador, and Hudson Bay. The trade is small now, averaging a total of 3,000 barrels per year before World War II. Accurate figures for the last few years are not available, but it is believed that only a fraction of that amount is now cured. The Atlantic salt salmon is sometimes known as "Halifax salmon" on the New York market. It usually sells several dollars a barrel higher than Pacific coast hard-salted salmon and is considered a fancier article. The method of salting is much the same as that used for curing hard-salted salmon on the Pacific coast.

Long before any permanent settlement was made, our ships visited the northern Pacific coast to put up cargoes of salted salmon which were later traded in Hawaii for sandalwood, which in turn was sold in China for furs, silk, teas, spices, or other oriental goods (Cobb 1930). Today Hawaii remains one of the principal markets for hard-salt salmon. Pickled or hard-salted salmon is packed on a commercial scale in Western Alaska. While pickled salmon is occasionally prepared at other points along the coast, no commercial packs have been made elsewhere for a number of years. A production of 829,000 pounds of hard-salt salmon is reported for 1940. This is less than half the average pack of the 1920's. Under market conditions of the past few years, the price of raw fish, salt, barrels, and labor has increased to such an extent that there is no margin of profit except to a few packers with an assured market and with surplus catches which it is not possible to can. It is expected that there will always be a market, though limited, for hard-salt salmon.

All five species of salmon are used to some extent in the preparation of hard-salt salmon, but red salmon (*Oncorhynchus nerka*) is the principal species used and yields the highest-grade product. A considerable amount of pink salmon (*O. gorbuscha*) and silver or coho salmon (*O. kisutch*) is also salted. While king (*O. tschawytscha*) and chum salmon (*O. keta*) are used rather extensively for noncommercial packs, very little of these two species is hard-salted commercially. Some pickled salmon bellies are still put up, but the pack is very small. Salted bellies are a choice product but under the present law, bellies may only be packed when the rest of the fish is used for food in another way. The major portion of the belly pack is made from pink salmon.

Most of the salmon used for brine-salting is taken by drift gill nets. In fact, 90 percent of the commercial catch in Western Alaska is made with this type of gear. Some fish are also taken by staked gill nets and beach or haul seines.

Raw Material Requirements

Quality is an essential consideration in packing hard-salted or pickled salmon. It is important to use only fresh fish, for soft bellies are very evident after salting. If the fish are not in the best condition the bones will come loose from the flesh and stand out, giving the fish a ragged appearance. Flavor, texture, and color are also inferior in the finished product if the salmon are not quite fresh when salted. Salmon approaching the spawning stage cannot be used because of discoloration of the skin and inferior flavor. The use of pews (single-tined fish forks) in handling the raw material is also detrimental. The holes made by the prong cause more rapid spoilage and leave dark streaks in the flesh, detracting from its appearance.

Butchering

When salmon are landed at the saltery they are washed, slimed, and beheaded. In heading, care is taken not to remove the napes or collar bone. Cutting follows the curve of the gill-flap opening. After heading, the fish pass to the splitters. There are two methods of splitting. In the first, the fish is split along the back, ending with a curving cut near the tail. The abdominal side is left as a solid section. Some two-thirds of the backbone is then taken out, and all viscera, blood, and membranes are scraped away. In the second method the fish is first split along the ventral side, eviscerated, and all membranes are scraped from the belly cavity. In splitting, the neck or head end of the salmon is toward the splitter, who makes a light incision at the neck end, just above the backbone. The whole side is then removed with one sweep of the splitting knife, leaving as little flesh as possible along the backbone. The knife is usually held so that the edge of the blade is at a slight downward angle. In removing the second side, two short cuts are first made under the backbone, one on each side, just about the region of the anal opening. Another slight cut is made under the neck end of the backbone, and one sweep of the knife removes the entire backbone and tail. The two cuts are made under the backbone to direct the course of the knife, preventing it from slanting too much in splitting. Slanting causes considerable flesh to be left on the backbone, which is, of course, wasted. Some curers make one or more longitudinal slashes in the flesh so that the salt will "strike" or penetrate more rapidly. The loss of weight in cleaning and splitting averages 25 percent.

Washing

After splitting, the salmon pass to the cleaners. These men scrape out blood clots and kidneys, and remove membranes, loose bones, or other offal. After cleaning, the fish are scrubbed thoroughly, inside and out, care being taken not to injure the flesh. A final cleaning is given in the washing tank and the salmon are then drained thoroughly, preparatory to salting.

Salting

Both round and square salting tanks are used. The tanks have no standard dimensions but the capacity should not be more than 100 barrels of fish. It is preferable to use several smaller tanks rather than one large one. If the tank is too large, pressure on the lower layers of fish is excessive, and the sides of fish in these layers are distorted or otherwise injured. Then, too, a large tank may be more than sufficient for a day's pack.

A thin layer of salt is scattered over the bottom. A layer of fish is then packed in, with flesh side up. No special system is followed in packing, the only rule being that the work should be done neatly, with the layers as level as possible. Each layer of salmon is covered with a thin layer of salt. Care must be taken that each fish is completely covered with salt. The tanks are filled several layers above the top, to allow for shrinkage, and the top layer is packed with the skin side up. A thicker layer of salt is used to cover the top layer. From 25 to 30 pounds of salt are required to cure 100 pounds of salmon. Several boards are laid across the fish as soon as the tank is filled and these are weighted down with large stones. This keeps the salmon submerged beneath the brine as it forms. The fish are allowed to make their own brine, which is formed as the salt extracts moisture from the flesh. The fish should be covered with brine at all times to prevent "rusting," that is, discoloration caused by oxidation. From 10 to 14 days will be required for this curing process, though the salmon may be left in the tank for a longer period of time. Curers do not agree on the loss of weight in salting. The best estimate at present is that about 15 percent of the moisture content is removed.

Grading and Repacking

The final step is repacking into barrels containing 200 pounds net weight, exclusive of brine. In repacking, the fish are washed in brine and scrubbed well, usually with a stiff brush, though pieces of burlap may be used. All slime, blood clots, excess salt, or other waste material should be removed. The salmon are then sorted into grades: (1) as to species (if more than one species is being cured); (2) color of flesh and skin according to whether the flesh is of good color and skin bright or flesh pale in color, with skin murky or discolored; and (3) as to quality, good or poor; that is, fish which were not strictly fresh when packed and have a characteristic odor and flavor, must be separated from the remainder of the pack.

After sorting, 200 pounds net weight of fish are weighed out for each barrel to be packed. A barrel of pickled or hard salmon requires from 40 to 52 red salmon, 25 to 35 coho (medium red or silver salmon), 70 to 80 pink salmon, 10 to 14 king salmon, and 25 to 30 chum salmon. The sides are packed flesh side up, except for the top layer. A liberal sprinkling of salt is scattered at each end, but only a little between the layers. If the fish have been properly cured, from 8 to 10 pounds of salt should be a sufficient amount for repacking a barrel of salmon. After the barrels have been headed they are filled with 100° salinometer brine through the bunghole. One end of the barrel is stencilled with the packer's name or brand, the species of salmon, and grade. The barrels should be inspected every few weeks while in storage to determine whether they are full of brine and are not damaged or leaking.

Salmon Bellies

A few salteries pack bellies, which are merely the ventral sections, the fattest and choicest portions of the fish. Because of the waste by this method, the preparation of this article was forbidden under the Alaska fishery regulations, unless some economic use was made of the remaining portion of the fish (Section 8, Act of June 26, 1906, 34 Stat. 480; 48 U. S. C. 236).

In preparing salmon bellies, the curer first cuts off the two pectoral fins and then removes the head. Care should be taken to follow the curve of the gill-flaps until the backbone is reached, when a straight cut may be made. With smaller salmon, the fish is then turned on its back, a knife inserted vertically in the body, the knife coming out just in front of the vent or anal opening. If made properly, the cut will come close to the upper wall of the belly cavity. With large king (also known as spring or chinook) salmon, it is sometimes necessary to make a cut on one side, then turn the fish over and cut through on the other side. The belly is then laid flat on the cutting table and the membrane at one end cut so that the belly will lie flat.

The bellies are washed thoroughly in clear, cold water, or in iced brine. The salting and curing process is identical with that for hard-salted salmon. Bellies are sent to the Seattle or San Francisco markets in barrels holding 200 pounds net, but are usually repacked for distribution to the retailer in kits or tubs of various sizes.

SPICED AND PICKLED FISH

Spicing and pickling is one of the minor methods of preservation used in North America, but it is very important in Europe and Asia, where a great variety of fishery products prepared with vinegar and spices have wide popularity.

The greatest development in pickled fish preservation in the western world was in Germany. Before World War II that country prepared the best spiced fishery products and also consumed the most products. Many of the published formulae are derived from German sources such as Hoffman (no date), Jacobsen (1926), and Stahmer (1925). There are said to be 200 different recipes for preparing spiced herring, and there are many other species of fish preserved with vinegar, salt, and spices. Other north European countries including Norway, Sweden, Denmark, the U. S. S. R., and the Netherlands produce a wide variety of pickled herring products.

In Japan, the Philippine Islands, and on the coast of China, the pickling of fish is even more important than in Europe. In fact, pickled fish is the most important single source of animal protein in Japan. Here fish are pickled in hot vinegar, either plain or spiced, without salting. Other methods include the pickling of fish in soy sauce, sake, and in a fermenting rice paste.

Spiced and pickled fish have been prepared on a small scale in the United States for many years, but prior to the war, much of the supply was imported. Stevenson (1899) describes the preparation of a number of spiced and pickled products. Until rather recently only a few articles were in demand, on a small scale, and almost entirely in cities with a large foreign population. Now there is a growing demand for pickled fish specialty products in the United States. The Swedish "smorgasbord" restaurants which have spread into a number of American cities have made some of these pickled fish items popular. The cocktail party vogue has also created some demand for pickled fish. Our tastes, too, are becoming more cosmopolitan.

Pickling with vinegar and spices is a very ancient form of food preservation, going back to prehistoric times. Stevenson (1899) believes that it probably antedates even pickling with salt. It is mentioned frequently in the writings of the Greeks and Romans, as witnessed by the citations of Smidth (1873) and Radcliffe (1921) in their excellent accounts of the fisheries of the ancients. Certain of these fishery products prepared with vinegar and spices were considered great delicacies, selling at such high prices that they were reserved for the banquet tables of the rich. One dish popular in Spain and in the Latin American republics of Central and South America today is "escabeche." It is prepared by frying fish in oil with bay leaves and spices, then marinating in vinegar and oil. This dish can be traced directly to the Romans, who in turn had it from the Greeks.

Pickling with vinegar was used extensively down through the Middle Ages, especially for fish that were fat and did not cure well by the very crude salting methods of the times. While the product did not keep so long, it was more appetizing than the dried and salted products of the period. Vinegar-pickled fish played a very important part in the food economy of the north European people down through the seventeenth century.

Brine-salted fish is often called "pickled," but this is a misnomer, if the name as applied to other food products is considered. Pickled foods are fermented in the process of manufacture with the formation of organic acids. If the amount of organic acids formed is not sufficient, more acid may be added in the form of vinegar; or vinegar may be used in the original cure instead of depending on the natural formation of acid. Therefore, only fish preserved with vinegar or vinegar and spices should be considered pickled.

PRESERVATIVE ACTION OF INGREDIENTS

Vinegar differs from salt as a preservative agent in that it does not preserve by osmosis, extracting water from the food, but enters into chemical combination with the product, reducing or inhibiting bacterial activity. The spices used may also have some slight value as a preservative; in fact through the Middle Ages pepper and other spices were valued as preservatives rather than condiments. Foods of this period were often very highly spiced, and it is probable that spoilage was masked rather than inhibited. Anderson (1925) believes that the preservative action of spices is in general insignificant and cites an experiment where an infusion of spice in water developed enough gas in two weeks to blow the cork out of the bottle. The preservative action of vinegar is probably due to the fact that spoilage molds are inhibited and bacteria greatly retarded, if the product has a low pH, that is, if the medium has an acid reaction. The active principle is the acetic acid in vinegar. According to Tressler (1923) an acid content of 15 percent is required to entirely prohibit bacterial action. Since commercial vinegars average 6 percent acetic acid content, and stronger vinegars reduced to this level are as low as 3 percent when used in food preservation, fish products put up in vinegar are only temporarily preserved. However, vinegars containing 3 percent acetic acid will preserve fish for months if the product is held in chill storage.

Tanner (1944) believes that the preservative action of vinegar is probably of little practical importance. He reviews recent work in this field and cites evidence that factors other than pH may be involved. It is suggested that the acetate radical may be more important than pH. The preservative effect of 0.75 percent of acetic acid is stated to be equal to 0.1 percent of sodium benzoate. He also states that in addition to the factors mentioned, others which are present in vinegar may exert an inhibitive action on microorganisms. Vinegar is known to contain propionic acid which has been shown to inhibit the development of molds.

REQUIREMENTS FOR INGREDIENTS

Fish used in the vinegar-spice cure must, of course, be of the best quality. Equally important, however, in obtaining a finished product of the highest grade, is the quality of the various accessory ingredients. The flavor, texture, color, and to some extent, the keeping quality are affected by the water, salt, sugar, vinegar, spices, herbs, and other miscellaneous ingredients.

The water must be potable and approved under all sanitary and health codes. Pond or shallow-well water should not be used. "Hard" waters are unsuitable, especially those with a high iron, calcium, or magnesium content. If the water supply is hard, the water must be filtered or a softener used. Brines should be boiled and filtered before use.

The vinegar should be clear, without foreign odors or flavors and should have a guaranteed acetic-acid content. Cider or other fruit vinegars should not be used because their acid content is extremely variable and the fruit esters in the vinegar might give the pickled fish an "off flavor." Distilled vinegar is recommended. Acetic acid diluted to the desired strength may be used. A 120 grain (2½ percent) malt vinegar is favored by some commercial packers. Vinegar should be titrated regularly to determine whether it has the required acid content. Wine may be used as a flavoring agent, as in a spiced wine sauce added to the pickled fish, but wine or wine vinegar should not be used in the original pickle cure.

The quality of the salt is also important. A high grade of purity is required. European curers prefer a Liverpool fishery salt. The salt must be as free as possible from calcium and magnesium compounds, as these impurities give a bitter flavor to the cured product. A coarse, half-ground salt will pit the surface of the pickled fish. A finely-ground cooking salt, guaranteed to contain less than one percent impurities and preferably mined, is recommended.

Experienced packers of spiced fish prefer a good grade of cane sugar. Some use is made of corn sugar but the quantity must be adjusted to obtain the same results with the standard formula. It is not a completely satisfactory substitute to date. This also applies to beet sugar. Saccharine has been used but is not recommended. It may be used in some countries but not in the United States where its use is prohibited by the Food and Drug Administration.

Spices should be bought whole and on the basis of chemical and microscopic examination. Buying specifications should require that the spices be fresh and of a high grade of purity. Ground spices should not be purchased as they may be readily adulterated with other plant material. Mixtures of whole spices may be composed of old or inferior spices. As a rule the curer should buy fresh whole spices, singly, and make up his own mixture. Spices should not be held much more than a year.

Essential spice oils should meet the requirements of the United States Pharmacopoeia. Both spices and oils should be bought only from well-known, reputable firms specializing in these products. "Bargain" spices are usually ruinous to quality products.

HERRING

Herring is the most important pickled fish product. Some of the more common pickled-herring products are appetitsild, Bismarck herring, cut spiced herring, gabbelbissen, gaffelbiter, Kaiser Friedrich herring, potted herring, rollmops, Russian sardines, gewurz herring, delicatessild, sur-sild, and smorgaas-sild. The names indicate that most of the spiced herring products prepared in the United States are of foreign origin. The composition of the sauce is the principal point of difference between many of these products. Kaiser Friedrich herring, for instance, are Bismarck herring in mustard sauce, while rollmops are Bismarck-herring fillets rolled around a piece of dill pickle. Bismarck herring are boned, with sides still joined, and packed in vinegar and spices.

Spiced herring packed in the United States is prepared entirely from fish cured during the fishing season, held in storage, and made into spiced-herring products as the market requires. Herring may be specially cured for this purpose, although Scotch-cured or Labrador salt herring may be substituted. Herring not specially cured for spicing is reported to have a shorter period of preservation, to be darker in color, lacking in flavor and tougher and more fibrous in texture. One of the most common methods for home preparation of salt herring is to pickle it with vinegar and spices. At one time salt herring were used extensively for commercial vinegar-pickled herring but such raw material is used today only when the stock of specially cured herring is exhausted, or in places where they cannot be obtained.

Most of the specially-cured herring are prepared from alewives or river herring (*Pomolobus pseudoharengus*) in the Chesapeake Bay area. Some are made from Atlantic herring (*Clupea harengus*) at Eastport, Maine, and a few neighboring localities. The Pacific herring (*Clupea pallasii*) is used from

Puget Sound to western Alaska. A variety of curing methods are used, of which the following is typical: The herring are cut or dressed as described in the salting of alewives. The cut herring are cleaned thoroughly, with special attention to removal of the kidney, which is the dark streak along the backbone. The fish are rinsed in fresh water and placed in a curing tank where they are covered with a brine testing 80° to 90° salinometer that contains 120-grain distilled vinegar amounting to an acidity of about 2½ percent. The fish are left in this brine until the salt has struck through, or completely penetrated the flesh. The fish, however, must be removed before the skin starts to wrinkle or lose color. The length of cure depends on the judgment of the curer and varies with the temperature conditions, freshness and size of the fish. The average length of cure is reported to be 5 days. Various sources of information give curing times varying from 3 to 7 days.

When the herring are sufficiently cured they are packed in barrels. These are often second-hand, previously used for soda fountain syrup. As a rule, no attempt is made to pack in regular layers. The herring are simply shoveled in until the barrel will hold no more. The barrels are headed, filled with a salt-vinegar brine testing 70° salinometer, and shipped to marketing centers such as Chicago or New York for final manufacture. There the herring are repacked in kegs which are then filled with a solution of distilled vinegar diluted with water to a 3 percent acidity, and containing sufficient salt to test 35° salinometer. Before the fish are repacked they may be cut into fillets or the backbone may be removed with the fish left otherwise whole. The kegs are then put into cold storage at 34° F. to be held until required.

The final process of manufacture is begun by soaking the herring in a tank of cold water from 8 to 10 hours. They are then removed, drained and placed in a solution of vinegar, salt, and water for 72 hours. The solution is made in the proportion of 1 gallon of 6 percent white distilled vinegar to 1 gallon of water and 1 pound of salt. The fish should be well covered with the solution. They are then made into cut spiced herring, rollmops, or Bismarck herring.

Cut Spiced Herring I

The vinegar-salt-cured herring are cut across the body in pieces 1 to 2 inches long. The sliced herring are then packed in 8-ounce tumblers or in 16- or 32-ounce glass jars, with whole mixed spices. The amount of spices added to each container is approximately one teaspoon to an 8-ounce tumbler, 2 teaspoons to a 16-ounce jar and 1 tablespoon to a 32-ounce jar. A slice or two of onion, a slice of lemon, or a strip of canned pimiento, and a bay leaf or two may be placed around the sides for ornament, depending on the preference of the individual packer. Each container is then filled with vinegar diluted to 2½ percent acidity, containing ½ pound of sugar ¼ pound of salt, 10 drops oil of cloves, 10 drops oil of allspice, and 10 drops oil of cardamom per gallon of solution. The spice oils are usually added to the sugar before dissolving it in solution to distribute the spice flavor more evenly.

The amount and variety of spice flavors may be altered to suit the taste of the packer or his market. The formula given is typical but is not claimed to be standard. The jars are vacuum sealed, wiped clean, labeled, and packed one or two dozen jars to the fiberboard carton. The length of preservation depends on the care in manufacture and the temperature of the storage. If held under refrigeration at 40° F. this product should remain in good condition at least 6 months. Exposure to light causes the herring to deteriorate more rapidly, even if held under refrigeration, as in a refrigerated show case.

Cut Spiced Herring II

The cut pieces of herring are packed in wooden tubs holding 10 or 20 pounds, or if they are to be repacked in individual glass containers, in kegs holding 100 pounds. A few spices, a bay leaf or two, and several slices of onion are placed in the bottom of the container, then a layer of cut herring, on which are laid spices and onion. This is repeated until the tub or keg is filled. The fish are covered with vinegar diluted with water in which the sugar is dissolved. The containers are then stored at 40° F. to cure for 10 days. At the end of this time if the fish are to be repacked, they are removed from storage and filled into 8-, 16-, and 32-ounce glass jars. The vinegar used in curing may be strained and re-used but some prefer to use fresh vinegar diluted to three percent acidity. A few of the spices, bay leaves and a little chopped onion are placed in each jar.

The quantities given in the formula below are sufficient for 10 pounds of cleaned herring. Whole spices are used in all recipes, unless otherwise specified.

10 lb. salt herring
2 oz. mustard seed
1 oz. bay leaves
1 oz. allspice
1 oz. black peppers
1 oz. white peppers
1 oz. red (chili) peppers
½ oz. cloves
2½ oz sugar
4 oz. onions, sliced
2 qt. water
2 qt. vinegar (6 percent acidity)

There are other recipes for the preparation of cut spiced herring. Cut spiced herring in tubs usually go to delicatessen shops or other wholesale outlets.

Rollmops

The vinegar-cured fillets are wrapped around a piece of dill pickle or a pickled onion. The rolls are fastened with wooden toothpicks, cured several days in a spiced-vinegar sauce, then packed in glass containers, generally of the same sizes used for cut spiced herring. Anderson (1925) made a comprehensive study of the packing of rollmops. The formula given here is the one recommended by him:

10 lb. salt herring
4 oz. chopped onions
2½ oz. sugar
¼ oz. whole cloves
1/16 oz. powdered nutmeg
1/16 oz. cracked cinnamon

¼ oz. mustard seed
¼ oz. chili peppers
⅛ oz. bay leaves
⅛ oz. whole black peppers
⅛ oz. whole white peppers
¼ oz. whole allspice
1/16 oz. cracked ginger
1/16 oz. crushed cardamom
2 qt. distilled vinegar (5 percent acidity)
8 qt. dill pickles

Put the bay leaves and chili peppers in a small cloth bag so they can be easily separated for later use. Place this bag together with the balance of the spices and three-fourths of a quart of vinegar into a covered receptacle. Bring to boil and allow to simmer for one and one-half to two hours. Violent boiling causes loss of the volatile acetic acid. A very simple way is to put the spices in a common fruit jar and place in boiling water for two hours. Allow to stand 1 to 2 weeks after boiling to insure still greater extraction of the spicing materials. Remove the chili peppers and bay leaves which are to be used for decorative purposes. Strain the pickle through a cloth bag to remove the spices. These should be well mixed, ready for adding to the jars before packing. Slightly less than three-fourths of a quart of pickle will be obtained.

Preparation of the fish Remove heads, scale, and wash. Split into two fillets and trim. Freshen two and one-half hours in running water, then drain. Ten pounds of medium size herring should give about 6 pounds drained weight.

Preliminary vinegar-cure Pack the fillets skin down in a stone crock. Cover with one and one-fourth quarts of vinegar. If necessary, put a light weight on top to keep the fillets well covered. Allow to cure in a cool place for 40–48 hours. Remove and drain. The vinegar should now test about 2 percent acid and show a salinometer reading of about 30°. The fish has absorbed much of the acid and has lost some salt.

Packing Cut each dill pickle lengthwise into four parts, then each of these across the center, making eight pieces in all.

Roll the fillets around a piece of pickle and fasten with a fresh clove. A clove serves the purpose just as well as a toothpick and adds to the attractiveness of the pack.

Place one teaspoonful of mixed used spices on the bottom of the jar, then pack the fish. With a medium sized herring, three rolls will pack nicely into a No. 306 jar (six fluid ounces capacity) if placed on end. Decorate around the sides with a couple of chili peppers and a bay leaf. Add sufficient pickle to fill from 25 to 35 cc. (this is about equivalent to two level tablespoonfuls). The net weight should be five and one-half ounces or over. Seal the jars immediately after packing. Vacuum sealing is preferable.

Store in a cool place. Cold storage at about 35° F. is advisable to insure longest preservation.

If vinegar-salt-cured herring are used, the preparation and preliminary vinegar-cure steps will be unnecessary. It is believed that a better product will be obtained if the vinegar-salt-cure herring are used. Test packs, by the writer, of Anderson's formula indicate that the spice-vinegar sauce should be diluted to 3 percent acidity, that the rollmops should be cured in the spice sauce for 10 days, then repacked in jars with a few spices, and the jars should be filled with fresh 3-percent vinegar with 2 tablespoons sugar and 1 of salt to the quart. Store at 34° to 40° F.

Bismarck Herring

The vinegar-salt-cured fish are treated as in the preparation of cut spiced herring up to the point of slicing. Instead of slicing, the backbone is removed, but the two sides are left joined together along the back and trimmed of thin ragged edges of belly flesh. The boned and trimmed fish are packed with vinegar and spice oils or spices as described for the preparation of cut spiced herring. They are left to cure at 40° F. for 10 days. At the end of this time, the fish are packed vertically in glass containers of sizes such as 8-ounce tumblers, and 16- or 32-ounce glass jars. A few fresh spices and a bay leaf with a slice of lemon or other similar decorative agents to suit the preference of the packer are placed around the sides of the jars. The jars are then filled with distilled vinegar, diluted to 3-percent acidity. The containers are sealed, cleaned, and packed into cartons.

Gaffelbiter

Take fat mild-cure salt herring, cut into fillets, and skin. The fillets are then freshened in running water 2 to 3 hours depending on the size of the herring, whether mild or heavy cure, and local market preference. The fillets are then cut into sections about one inch in length and packed in tubs or small crocks, with chopped onion, bay leaves, whole black peppers, whole cloves, and mustard seed, mixed with the fish. The herring are then covered with distilled vinegar, from 3 to 5 percent acidity, and left to cure in cool storage (about 40° F.) for 48 hours. They are then packed in glass containers, filled with fresh vinegar or the vinegar used in curing, but strained before reuse. The jars are sealed, wiped, and packed into cartons.

This product differs from gaffelbiter as prepared in the Scandinavian countries. It is descriptive of the method as developed in the United States for the Scandinavian-American market. The formula was obtained from a Scandinavian-American fish curer. The ingredients are given below:

16 lb. mild-cure herring
1 qt. vinegar (6 percent distilled)
1 qt. water
8 oz. chopped onions
¼ oz. whole black peppers
¼ oz. whole white peppers
¼ oz. whole cloves
¼ oz. mustard seed
⅛ oz. bay leaves

Gabelbissen

Fresh fat herring is used for gabelbissen. The round herring are first cured for 30 to 40 hours in a brine testing 90° salinometer. In some instances, however, this preliminary brine cure is omitted and the fresh fish are packed directly into barrels. A special curing mixture is scattered on the bottom of the barrel between the fish and over each layer. The herring are packed much as described for the packing of whole salt herring, with bellies straight up and tails overlapping. The layers of fish are packed in rather loosely. The barrels are headed up and put in cold storage at about 40° F., where they are held for several months to cure and ripen.

At the end of about three months the herring are removed from storage, drained well, headed, boned, and skinned. The fillets may be cut into sections and packed in glass containers, or whole fillets may be packed in oval or oblong flat cans. A bay leaf and a thin slice of lemon may be laid in each can. The containers may be filled up with the original curing brine diluted one-half with distilled vinegar or they may be packed in wine sauce, dill sauce, or curry sauce. The containers are sealed, cleaned, packed in cartons and held under refrigeration until sold to the retail consumer. The curing mixture is as follows:

220 lb. herring	4 oz. cardamom
22 to 35 lb. salt	2 oz. ginger
4 lb. sugar	6 oz. hops
2.2 lb. black peppers	2 oz. cloves
2.2 lb. white peppers	2 oz. cinnamon
18 oz. allspice	3 oz. saltpeter
11 oz. coriander	

The spices are ground coarsely, at the time the mixture is made up, and mixed thoroughly with the salt, sugar, and saltpeter.

Matjeshering

This is another spiced-herring product considered very choice in northern Europe. It is prepared from fresh, full herring, that is, herring with milt or roe. The fish are first washed and scaled. Then the gills are removed and the intestines are pulled out through the gill opening so that the throat or belly wall are not cut open. The fish are soaked from 12 to 18 hours in a 7 percent solution of white wine vinegar. They must be taken from this solution before the skin becomes soft and flabby.

They are wiped dry and rolled in a curing mixture consisting of 2.2 pounds salt, 1.1 pounds brown sugar, and 4 ounces saltpeter. This amount is supposed to be sufficient for the unit quantity, a small keg of 75 herring. The next step is to pack the herring in small kegs, with the backs up and the layers straight. Some of the curing mixture is scattered between the fish as they are packed and some is sprinkled over each layer.

After 24 to 48 hours the fish are repacked, using the original brine. If enough brine has not formed, sufficient additional brine to cover the fish is made from one part of the salt-sugar mixture to four parts water. This is boiled, cooled, and filtered before using. The kegs are stored at 40° F. for at least one month or until the product is considered ready for use.

Gewurzhering

This product is prepared in the same way as matjeshering, but spices are added to the curing mixture.

75 herring	1 oz. ginger
4 oz. black peppers	1 oz. cloves
2 oz. chili peppers	1 oz. cinnamon
2 oz. allspice	1 oz. nutmeg
1 oz. coriander	

The spices are ground and added to the salt-sugar mixture when it is made up.

Russian Sardines I

This is a favorite product in northern Europe, where large quantities are prepared. It has been packed in the United States for about 80 years. Production has been small of recent years since this product requires small herring of the size most desirable for Maine sardine canning. There are several different methods of cure, of which two are given here.

Wash and scale 10 pounds of small, fresh round herring (from 5 to 7 inches). Remove the gills and as much of the intestines as possible by pulling them out through the gill flap without tearing the throat or belly. Rinse again, drain, and pack in a large crock or tub. Cover with 3 parts of distilled vinegar and 1 part water. For this amount of fish, 3 pints of 6 percent distilled vinegar and 1 pint of water will be required. Allow the herring to stand for about 12 hours.

10 lb. fresh herring
2 lb. fine salt
1 lb. powdered sugar
1 oz. allspice
1 oz. black peppers
½ oz. saltpeter
½ oz. bay leaves
½ oz. cloves
½ oz. ginger
½ oz. hops
½ oz. nutmeg

The spices should be finely ground just before use and blended with the other ingredients.

After the fish have drained, they are dredged in the spice mixture and packed in crocks or tubs, bellies up. A small additional amount of the mixture may be scattered between each layer. The layers should be packed at right angles to each other with the top layer packed backs up. The balance of the spice-curing mixture is scattered over the top layer and the fish are weighted down so that they will be entirely covered when the brine forms. Some packers also scatter chopped onions, ground or sliced horseradish, and capers between each layer. The amounts of these ingredients required for 10 pounds of small herring are: ½ pound onions, ¼ pound horseradish, and a small bottle of capers (about 2½ ounces). The fish are held in cool storage for at least 2 weeks before repacking in small kegs holding about 7 pounds, or in glass jars. The brine formed in curing is filtered and poured into the containers before closing.

Russian Sardines II

Fresh small herring (5 to 7 in.) are packed in 90° to 100° salinometer brine as soon as possible after catching. They are left in the brine about 10 days until they are thoroughly salt-cured or struck through, the exact time depending on the size of the fish and the weather. The salted fish are then headed, pulling out the viscera with the same stroke of the knife without tearing the belly open. They are then washed in clean water and placed on wire trays for draining. After the herring have drained for several hours they are taken to packing tables where they are sorted according to size. Each size is packed separately in small kegs holding about 7 pounds each. A scattering of spices and flavoring ingredients is laid in the bottom of the keg. A layer of herring is placed with backs up. The layer is then pressed down slightly. A thin layer of spices and a little vinegar is then added. The process is repeated until the keg is filled. As much vinegar as the keg will hold is then poured in and the container is headed up. The fish require some time to season before they are put on the market. In summer they are ready for sale in 4 or 5 days but in winter 3 or 4 weeks may be required. If the product is held in refrigeration at about 40° F. it will remain in good condition for a year. Stevenson (1899) gives the following ingredients as sufficient to cure 120 pounds of herring:

120 lb. fresh herring.	½ lb. ginger
	4 lb. sliced onion
2 gal. vinegar	2 lb. horse-radish
1.5 lb. allspice	½ lb. chili peppers
1 lb. bay leaves	½ lb. coriander seed
½ lb. cloves	2½ oz. capers

Other spices may be used to suit the preference of the market and packer.

Potted Herring

This is a pickled herring dish greatly appreciated in the British Isles. Fresh herring are always used. The herring are first scaled, headed, split down the belly, and washed thoroughly. After draining, the inside of each fish is rubbed with a mixture of black pepper and fine salt. The herring are then laid in layers in a baking dish with a few whole cloves and bay leaves scattered over the layer of fish. When the dish is filled the fish are half-covered with vinegar and the dish is baked in a moderate oven (about 350° F.). This product will keep about 2 weeks at ordinary temperatures (Jarvis 1943a). Additional preparation in a somewhat different form is described in another section of this report. Small mackerel are also cured by this method.

Scandinavian Anchovies I

The true anchovy is not used in the preparation of this product. The bristling or sprat (*Clupea sprattus*) is used. In contrast to the Spanish or Portuguese anchovies (p. 157, ibid), Norwegian or Swedish anchovies are flavored with spices and the curing is not primarily a fermentation process. Various spice mixtures are used and the methods differ in detail but the following is typical: From 25 to 30 pounds of brisling are cured for 12 hours in a brine made of 4½ pounds of Liverpool salt and 7 quarts of water. At the end of the salting period the fish are laid on a wire screen to drain. The spice-salt mixture is then made up, with all spices well pulverized and the ingredients thoroughly blended. The sprats are stirred well in half of the spice mixture and packed in a large container where they are left to cure for 14 days. They are then repacked in individual containers in layers, bellies up. Some of the remaining spice mixture is scattered between each layer, with pieces of chopped bay and cherry leaves. On the bottom and on the top of each container two whole bay leaves are laid. The brine formed in the original spice cure is filtered and used to fill the smaller containers after packing. During the first few days after the containers are closed they must be rolled about and inverted at least every other day (Hoffman; undated).

The ingredients for the spice mixture and the amounts for the quantity of fish given here, are as follows:

2¼ lb. Luneberg salt	3 oz. sugar
	½ oz. cloves
3 oz. black peppers	½ oz. nutmeg
3 oz. allspice	½ oz. cayenne

Tin containers are preferred to wooden kegs, which are often leaky and the airtight seal of tin containers permits a longer period of preservation.

Scandinavian Anchovies II

Fresh brisling are placed in a strong salt brine from 12 to 24 hours. They are drained on a screen, and are packed in layers in small kegs after being rolled in a spice-curing mixture. Some of this mixture is scattered between the layers of fish. At the top, bottom, and in the middle of the keg, several bay leaves are laid. The kegs are packed tightly and are rolled about or inverted for 14 days. The anchovies may be repacked in tins in 14 days in summer or after 4 to 8 weeks in winter.

40 lb. brisling
2¼ lb. Luneberg salt
7 oz. black pepper
7 oz. allspice
7 oz. sugar
1⅛ oz. cloves
1⅛ oz. nutmeg
1⅛ oz. Spanish hops

The spices are ground and mixed with the salt.

Scandinavian Anchovies III

A third formula, from German sources, is as follows: The brisling are brine-salted in Norway in barrels holding about 100 kilograms (220 lb.). When the brisling are to be manufactured into anchovies, the barrels are taken out of cold storage and the fish washed throoughly in a light brine testing 40° salinometer. After draining, the fish are packed loosely in new barrels with some of the spice mixture scattered between each layer of fish. The brine used for washing and the original brine are filtered and poured into the barrels after filling. The barrels are placed in cool storage for several months for the fish to ripen or acquire an aromatic flavor. The barrels should be rolled about daily or at the least, at intervals of two or three days. When the fish have completely absorbed the spice flavor they are repacked in small individual containers, small kegs holding about 7 pounds, cans holding from 2 to 5 pounds, and glass jars. The brine used in curing is filtered and filled into the containers when they have been packed with fish. In summer 0.5 percent benzoic acid may be added to the brine.

The spice mixture, in quantity for one barrel original weight, is as follows:

2 lb. black peppers
1 lb. allspice
1½ lb. sugar (best raw)
1 lb. saltpeter
1 lb. bay leaves
6 oz. Spanish hops
2 oz. mace
2 oz. cloves
2 oz. cinnamon
2 oz. ginger

Appetitsild

The largest size Norwegian style anchovies cured by the method just described are selected and after heading are cut into fillets, removing the backbone. The fillets are packed in oblong flat cans, flesh side up, with a bay leaf and a thin slice of lemon in each can. Filtered curing brine is poured into each can, which is sealed immediately. The cans are not processed.

Small fat herring may also be used in the preparation of anchovies or appetitsild. According to Jacobsen (1926), brisling, when cured as anchovies, should have a salt content of 10 percent and a moisture content of 40 percent. Fat herring when cured as anchovies should have a salt content of 14 percent and a moisture content of 45 or 50 percent. The blend of spices in anchovy curing is considered very important. The flavor must be a blend, with no single spice predominating. The best storage temperature is considered to be about 40° F.

Herring in Sour Cream Sauce

Mild-cure salt (Holland style) herring are filleted, saving the milts. The fillets are soaked in cold water for two hours. The milts are rubbed through a fine sieve. The fillets are drained of surplus moisture. The vinegar, wine, and spices are boiled together for a few minutes, then cooled, and after removing the spices, stirred into the sour cream, sweet cream, and milts. The fillets are packed in a container with sliced onions, then covered with the sauce. The whole is allowed to marinate in a cool place one week. The fish are then packed in glass jars, which are then filled with the sauce.

1 gal. keg Holland style herring
1 pt. white wine, dry
1 pt. sour cream
1 pt. sweet cream
½ pt. distilled vinegar
½ oz. mixed spices
2 cups onions, sliced thin

Herring in Wine Sauce

Wine sauce formulas in general are like the standard spice sauce formulas for herring, with the exception that the amount of vinegar is reduced one-half or three-fourths and wine used instead. A dry white, or burgundy-type red wine must be used. Sweet wines are not suitable. A sample wine sauce is given as follows:

1 qt. white wine
1 pt. vinegar, distilled (white)
4 oz. chopped onions
2½ oz. sugar
¼ oz. whole cloves
¼ oz. mustard seed
¼ oz. chili peppers
⅛ oz. bay leaves
⅛ oz. whole black peppers
⅛ oz. whole white peppers
¼ oz. whole allspice
1/16 oz. ground nutmeg
1/16 oz. cracked cinnamon
1/16 oz. cracked ginger
1/16 oz. crushed cardamom

First, the vinegar and wine are poured into a large covered jar, and the onions, sugar, and spices added. The jar is placed in a pan of boiling water for two hours. The jar is allowed to stand overnight. When the sauce is ready to be used it is strained to remove the spices.

If vinegar-salt-cure herring are being used, the herring fillets are cut in pieces of suitable size, rinsed in fresh water, drained, and packed in glass jars with a few fresh spices, such as bay leaves, chili peppers, and a slice of lemon. The jars are filled with wine sauce, then sealed. The amount of sauce above is enough for about 10 pounds of fish.

If ordinary salt herring are used, they are filleted and freshened in water. The drained fillets are packed in a stoneware crock, covered with 1 quart distilled vinegar 3 percent acidity (for 10 lb. herring) and allowed to stand 48 hours. The fillets are then cut in cubes and packed in jars, which are filled with wine sauce.

SALMON

Pickled salmon is packed commercially only in a few localities in northern Europe. It is prepared to some extent in the United States but only for local use. Properly made, it is an appetizing article of food, with a length of preservation about equal to other pickled fish. Commercial formulae are derived from old, home recipes. Representative examples are given here.

Formula No. 1

Ten pounds of salmon are cut into individual serving portions. The pieces are washed well in cold water then drained and dredged in fine salt. The salt is drained off after 30 minutes, and the salmon simmered slowly until done. The warm fish are placed in an earthenware crock and covered with a vinegar spice sauce made as follows:

1 qt. distilled vinegar
1 qt. water
½ cup olive oil
1 cup sliced onions
½ tbs. bay leaves
1 tbs. white peppers
1 tbs. mustard seed
½ tbs. cloves
½ tbs. black peppers

Cook the onions in olive oil slowly until they are yellow and soft. Add the rest of the ingredients and simmer the whole gently for 45 minutes. Allow the sauce to cool, then pour it over the fish, making sure that all pieces are covered. Allow the fish to stand for 48 hours then repack it in pint jars, with a slice each of lemon and onion and one bay leaf around the sides for decoration. Filter the spice sauce, then pour it over the top of the fish until the container is filled, then seal. This product should be held at 40° F. The method may also be used for shad and other large fish.

Formula No. 2

This formula was obtained from a Scandinavian source. The salmon must be absolutely fresh. After it has been well washed, the backbone is removed and the sides trimmed of the very thin belly flesh. It is then cut in small pieces of about one-fourth pound each. These are simmered in well salted water until they are done but not soft. A sauce is made of the water used in cooking (first filtered), equal parts of white wine and vinegar. The pieces of salmon are packed in wide-mouth glass jars with two or three thin slices of lemon, two bay leaves, four cloves, and four whole black peppers to each jar. The sauce is poured over the fish while still warm, so that all pieces are completely covered. A three-fourths-inch layer of olive oil is poured in the top of each jar. The jars are sealed and then stored in a dry, cool place.

Some mild-cure salmon is cut into two-inch cubes, freshened in cold water, and packed in spiced vinegar sauce or in wine sauce.

MACKEREL

Fillets

This formula, developed for mackerel, may be used for other fish. It has been obtained from German sources. The fish is cleaned and washed thoroughly, then cut into fillets, removing the backbone. Divide the fillets into 2-inch lengths and dredge in fine salt. Pick up with as much salt as will cling to the flesh and pack in a crock or tub. Let the fish stand for one to two hours, then rinse in fresh water. Cook the vinegar, water and other ingredients slowly and gently for 10 minutes after reaching boiling point. Add the fish and cook slowly for 10 minutes longer, counting from the time at which the solution again begins to boil after the fish has been put in. Remove the fish and allow the pieces to drain, then pack them in sterilized jars, adding some chopped onion, a bay leaf, a few spices, and a slice of lemon to each jar. Strain the spice vinegar sauce and bring to a boil. Fill the containers with hot sauce and seal immediately. Store in a cool, dry place.

- 10 lb. mackerel fillets
- 2 qt. distilled vinegar
- 3 pt. water
- 2 cups chopped onion
- 1 clove garlic, chopped
- 2 oz. sugar
- 1 tbs. allspice
- 1 tbs. cloves
- 1 tbs. black peppers
- 1 tbs. bay leaves
- 1 tbs. crushed nutmeg

HADDOCK

Fillets

This formula is designed for haddock but may be used for almost any other large fish. The haddock are cleaned carefully, skinned, and cut into fillets, removing the backbone. The fillets are cut in pieces about 2 inches square. These are washed, drained, then put in a tub and covered with a 90° to 100° salinometer brine. They are left in brine from 1 to 6 hours, depending on individual preference. The fish are rinsed in fresh water, then packed in a crock or large pot as follows: A few spices and pieces of sliced onion are scattered on the bottom. Then, pack in a layer of fish, cover with a scattering of spices and sliced onion, and continue until all the fish are packed. The fish are covered with a solution of two parts vinegar and one part water, adding a small piece of alum about the size of a walnut. Boil slowly until the fish may be pierced easily with a fork. After cooling, the product is packed in glass containers, adding a few fresh spices, a bay leaf, and a slice of lemon around the side of the jar for decoration. A few slices of onion may also be packed with the fish. Strain the vinegar sauce, heat it, and pour over the fish until the top is well covered. Seal the containers immediately. For maximum preservation, store this product under refrigeration. Amounts given below should be sufficient for 10 pounds of fish ready for pickling:

- 10 lb. haddock fillets
- 2 qt. distilled vinegar (6 percent)
- 1 qt. water
- ½ oz. white peppers
- ½ oz. chili (red) peppers
- ½ oz. allspice
- ¼ oz. cloves
- ¼ oz. mustard seed
- ¼ oz. bay leaves
- ¼ lb. sliced onions

STURGEON

This method is used for sturgeon, pike, pickerel, salmon, herring, trout, and other fish. It is a commercial formula of German origin. Ten pounds of fish are washed well and cut in small individual serving-size portions, from 2 to 4 ounces each. These pieces are dredged in fine salt and left from 1 to 3 hours. The salt is rinsed off, the pieces are dried, and brushed with good cooking oil. They are laid on a grill and broiled over a hot fire until both sides are a light brown. They should be brushed with cooking oil during the process. The fish is allowed to cool, then packed in glass containers with a slice or two of lemon, bay leaves, onion, and a scattering of rosemary, whole black peppers, and whole cloves between the layers of fish. The jars are filled with a marinade made of white wine, vinegar and water, sealed immediately, and stored in a dry, cool place.

10 lb. sturgeon
½ lb. lemon slices
½ lb. sliced onions
1 oz. whole black peppers
½ oz. whole cloves
1 qt. white wine
1 qt. distilled vinegar
1 pt. water
¼ oz. rosemary

Thyme may be substituted for rosemary, and the spice combination may be otherwise altered to suit the individual preference.

Escabeche

This recipe is of Spanish origin. Escabeche was brought to Spain by the Romans who, in turn, had it from the Greeks. It is probably the most popular Spanish method of preserving fish and is found in all Latin-American countries. Though there are many local variations, all are founded on the basic recipe. Mackerel, kingfish (king mackerel), tuna, and corvina are the fish most used for escabeche. Almost any fish may be used although soft-fleshed fish do not make so good a product.

10 lbs. fish
1 qt. distilled vinegar
2 tbs. bay leaves
1 tbs. black peppers, whole
1 pt. olive oil
1 tbs. red (chili peppers)
½ tbs. cumin seed
½ tbs. marjoram

Cut the fish into small serving portions. Wash the pieces thoroughly, drain and place in a 90° salinometer brine for ½ hour. Then wipe the fish dry. Pour the olive oil into a frying pan, together with a clove of minced garlic, half a dozen bay leaves, and a few red peppers; then heat the pieces until they are light brown in color and lay aside to cool.

Add onions to the oil and cook them until they are yellow. Then add black peppers, cumin seed, marjoram, and vinegar. Cook slowly for 15 to 30 minutes and cool. When the fish are cold, pack into sterilized jars with the rest of the bay leaves and red peppers. Fill the jars with sauce and close immediately. This preparation may be used after 24 hours but it tends to improve with storage. It will keep about 3 weeks in summer; much longer if stored in a cool place.

Pickled Eels

This dish is a favorite in northern Europe, from the British Isles to Sweden. Clean and skin the eels and cut them into pieces about ¾-inch thick. Wash and drain the pieces, then dredge in fine salt and allow to stand from 30 minutes to 1 hour. Rinse off the salt, wipe the pieces dry, and rub them with a cut clove of garlic. Brush the eel with melted butter and broil until both sides are a light brown. As an alternative, pieces may be sauted in olive oil or other good salad oil. Places the pieces of cooked eel on absorbent paper. When the pieces are cool, pack them in layers in a crock with a scattering of sliced onion, allspice, bay leaves, mustard seed, whole cloves, peppers, and mace between the layers of fish.

Weight the mixture down to keep it compressed. Cover the fish with a cold vinegar sauce made of vinegar, water, onions, and a few bay leaves cooked for 15 to 20 minutes. After standing for 48 hours in a cool place pack the eels in glass tumblers with a thin slice of lemon, a bay leaf, a slice of onion, and a few fresh whole spices for decoration. Fill the tumblers with sauce used in curing, which has been filtered. Seal the containers immediately. Store in a cool, dry place. This article remains in good condition for a considerable period of time.

OYSTERS

In the eighteenth and nineteenth centuries pickled oysters were prepared commercially over most of the Atlantic coast area. According to Stevenson (1899) pickled oysters were consumed extensively around New York during the Christmas holidays. They are not nearly so popular now and are usually prepared only for special orders. Some pickled oysters are prepared in Virginia for local consumption. Various formulae are available, some from traditional colonial sources, while others may be found in French or other continental cookbooks. Two typical formulae are given here:

Virginia Pickled Oysters I

Open one gallon of oysters, saving the liquor. Strain the liquor and add sufficient salted water to bring the amount up to 3 pints. Simmer the mixture gently over a low flame. When the liquor is near the boiling point, add the oysters a few at a time, cooking until the "fringe" curls. The oysters are then removed from the liquor and set aside to cool. Make a sauce of vinegar, white wine, bay leaves, onion, garlic, parsley, fennel, thyme, cloves, black pepper, allspice, cinnamon, and mace. Add this sauce to the oyster liquor and simmer 30 to 45 minutes. When it is cool, pack the oysters in glass jars with a bay leaf, slice of lemon, and a few fresh spices in each jar. Strain the liquor and when it is cool pour it into jars, seal immediately, and store in a cool, dark place. The oysters are ready for use in 10 to 14 days.

1 gal. shucked oysters
3 pt. oyster liquor
1 pt. distilled vinegar
1 pt. white wine, dry
2 tbs. ground onion
2 cloves garlic, crushed
2 tbs. bay leaves, crushed
1 tbs. chopped parsley stems
1 tbs. crushed fennel
1 tbs. crushed allspice
1 tbs. crushed black peppers
1 tbs. crushed cloves
1 tbs. crushed stick cinnamon
¼ tbs. crushed mace
¼ tbs. crushed thyme

Pickled Oysters II

Blanch one gallon of freshly opened oysters until the fringe curls. Remove the oysters and set them out to cool. Bring the liquor used in blanching to the boiling point, then set aside to cool. At the same time cook the vinegar and spices together slowly, after which strain out the spices. Combine the oyster liquor and spiced vinegar. Pack the oysters in glass tumblers with a bay leaf and a thin slice of lemon in each. When the sauce is cool, strain it and pour over oysters until the containers are filled. Seal the tumblers immediately and store in a cool, dark place.

1 gal. shucked oysters
2 qt. oyster liquor
1 qt. vinegar
½ oz. cloves, whole
½ oz. allspice, whole
½ oz. black peppers whole
1 blade mace

Mussels

This formula may also be used in pickling clams and oysters. Scrub the shells well and steam just enough to open the shells. Save the liquor or nectar. Remove the meats from the shells, cutting out the byssus or beard. Cool meats and nectar separately. When cool, pack the meats in sterilized glass jars with a bay leaf or two, a few whole cloves, and a thin slice of lemon to each jar.

Strain the liquor obtained in steaming the shellfish. To each quart of liquor add one-half pint distilled vinegar, one-half tablespoon each of allspice, cloves, and red peppers, with one-quarter teaspoon of cracked whole mace. Some recipes for pickled mussels call for white wine or wine vinegar instead of distilled vinegar. The amount of wine or vinegar is a matter of personal taste. Simmer for 45 minutes. When the sauce is cool, pour into the jars, and seal. Store in a cool, dark place. This product will be ready for use in about two weeks. Pickled mussels and oysters turn dark if exposed to the light.

SHRIMP

Pickled shrimp is a regional specialty of the New Orleans area but is sold in fish markets from Key West to Washington, D. C. There are no standard recipes but those given here are believed to be typical.

Pickled or Spiced Shrimp Formula I

Peel the green shrimp and wash them well. Make a brine of 1 gallon water, ½ cup salt, 1 pint distilled vinegar, 1 tablespoon red peppers, ½ tablespoon cloves, ½ tablespoon allspice, ½ tablespoon mustard seed, and 6 bay leaves. Simmer the brine slowly for ½ hour, then bring it to the boiling point and add the shrimp. When they have cooked for 5 minutes, counting from the time the brine again begins to boil, they should be removed and allowed to cool. Pack in sterilized jars with a bay leaf, a few fresh spices, and a slice of lemon in each jar. Fill the jars with a solution made in the proportions of 2 pints of water, 1 pint of 5 percent distilled vinegar, and 1 tablespoon sugar. Seal the jars tightly and store in a cool, dark place. These pickled shrimp keep longer than those prepared by the second method, but the second pickled shrimp product requires less labor and is cheaper.

Pickled or Spiced Shrimp Formula II

Take 5 pounds of fresh, green headless shrimp. Wash them well but do not remove the shells. Put celery tops, salt, parsley, thyme, bay leaves, vinegar, and spices into the water. When this has boiled about 45 minutes, add the shrimp. Let boil 10 minutes, then set the pot aside and allow the shrimp to cool in the liquor. Drain and pack in small cartons with some of the spices. This product remains in good condition only a very short time unless held under refrigeration.

5 lb. shrimp
1 gal. water
1 pt. vinegar, distilled
2 cups salt
1 bunch celery tops
1 small bunch parsley
1 tbs. allspice
1 tbs. bay leaves
1 tbs. red (chili) peppers
1 tbs. black peppers
½ tbs. cloves
1 blade mace

CAVIAR AND OTHER FISH ROE PRODUCTS

The roes or eggs of fish are among the most valuable of the miscellaneous food products from fishery sources. With few exceptions, almost any species may be utilized if the roe is large enough. The roes of sturgeon, salmon, mullet, alewife, whitefish, sea herring, cod, haddock, and tuna are the most important ones used in fish curing. A variety of curing methods may be used. Sea herring roe is air dried by Alaskan Indians. Sturgeon and salmon eggs are salted in brine and sold under the name caviar. Mullet roes are dry-salted, salted and air-dried, and brine-cured in the southern Atlantic States. Cod roe is salted and smoked in the northern European countries. Tuna roe is salted and air-dried in the Mediterranean area. Alewife and whitefish roes are cured as caviar in the United States.

CAVIAR

Caviar may be made from the roe of various species of fish but in the popular mind, caviar and sturgeon are synonymous. The reason for this belief is that sturgeon caviar was the first variety to be sold commercially, is the most important, and is the highest in quality and in price. This idea is so firmly fixed that the U. S. Food and Drug Administration has ruled that "it is believed that the name of the particular fish from whose eggs caviar is made should appear on the label. In the case in point an appropriate label would be whitefish caviar."

At the end of the nineteenth century and in the early years of the twentieth, the United States had an annual production of 300,000 pounds of sturgeon caviar (Stevenson 1899). Most of this was exported to Germany (Stahmer 1925). Today less than 1,000 pounds of sturgeon caviar are cured in the United States annually. Roe from other species is now cured in the United States and Alaska; for example, in 1940, 291,518 pounds of salmon caviar, 86,496 pounds of whitefish caviar (Fiedler 1945) and an undetermined amount from other species were cured. Instead of exporters we have become importers of caviar. In 1945, imports of caviar and other fish roe amounted to 86,337 pounds of sturgeon caviar, 144,463 pounds of other fish roe and 26,101 pounds of caviar, boiled (pasteurized and in hermetically sealed containers). (Anderson and Power 1946).

The American Caviar Industry

About fifty years ago the sturgeon was a common fish in American waters. In 1888 the catch of sturgeon was 17,879,000 pounds (Radcliffe 1925). In that year a single packer on the Delaware collected and shipped to Europe about 100,000 pounds of sturgeon caviar. When caviar and smoked sturgeon became popular, the prices of these products rose rapidly and fishermen found that sturgeon fishing was a very profitable occupation. As a result the waters were badly overfished. In addition many small sturgeon, taken while fishing for other species, were destroyed. Some of the rivers, notably the Delaware and Hudson, once important for large catches of sturgeon, became so badly polluted that fish could not live there. As a result of all these causes, the sturgeon has been almost exterminated. Today the fisherman who catches the "cow" sturgeon usually prepares the caviar himself and sells it either to a local buyer or a dealer in the New York wholesale market.

In America, caviar is prepared from the roe of the following species of sturgeon: On the Atlantic coast, the common sturgeon (*Acipenser oxyrhynchus*); in the Great Lakes region, the lake sturgeon (*A. fulvescens*); on the Gulf coast, the short-nosed sturgeon (*A. brevirostrus*); on the Pacific coast, the green (*A. acutirostris*) or white (*A. transmontanus*) sturgeon; and in the Mississippi River valley, the shovel-nosed sturgeon (*Scaphirhynchus platorynchus*) are used. Roe from the last-named species is reported to make the poorest grade of caviar.

The sturgeon are caught in large mesh drift-gill-nets, similar to salmon gill-nets in construction and operation, and, especially in the Columbia and Mississippi river areas, on set- or trot-lines. A few sturgeon are taken in haul seines and traps. Gill-net fishing is most effective at night and in localities where the water is not clear. As the sturgeon are bottom feeders many of the sturgeon gill nets are operated as "sunken" gill nets, just scraping the bottom.

To make good caviar, the roe of the sturgeon should be taken just before it is fully developed or "ripe," and while it is still hard. If the roe is immature or "green" it does not make a good grade of caviar. Soft, fully developed roe in spawning condition also makes an inferior product.

The amount of roe obtained from an individual fish usually runs from 10 to 70 pounds, varying with size, species, and locality. Occasional large specimens may yield more than 100 pounds of roe.

The "cow" sturgeon should be landed as soon as caught, the belly slit, and the roe removed. The roe must not be washed with fresh water as this tends to soften and break the shells of the individual eggs. It is also reported that roe washed in fresh water will not cure so well and is inferior in both texture and flavor. Exposure to direct sunlight is also a cause of deterioration. Rigid cleanliness and speed in handling are essential to production of a good quality caviar.

The roe is placed on a work table with part of its surface made of a ¼-inch wire-mesh screen. A second finer mesh screen below this slants at a 45° angle into a large tub. Some curers place a sieve with a ¼-inch mesh directly over a large wooden mixing tub. The egg sac is slit carefully so that the individual eggs are not damaged and the roe is separated into portions. The curer rubs portions of the roe on the sieve gently, using the full palm of the hand. The individual eggs are separated from the membrane and fall through the mesh onto the screen below, sliding gradually into the tub. Slime, blood, and bits of membrane drain through the second screen. Vigorous rubbing is apt to crush many individual eggs, and to force pieces of tissue and other foreign material through the mesh of the sieve. This foreign material must then be separated from the eggs in the mixing tub, thus delaying the curing process.

Radcliffe (1925) suggests that:

> Operators who prepare large amounts of caviar will find it convenient to fit the coarse sieve over a zinc-lined trough and rub the eggs into it. One type formerly used was 18 inches deep and 2 feet wide by 4 feet long. The bottom was sloping and had an opening at the lower end, closed with a sliding door underneath, the eggs being drawn off through the opening into the mixing tub.

The eggs, which look like small shot, are now ready for salting and mixing. Caviar makers claim that quality depends largely on skill in salting and type of salt used. Some caviar makers with European experience claim that the best quality caviar can only be made if Luneberg or Russian caviar salt is used. Others report excellent results with the mild-cure salt used for salmon. All agree that the salt must be distributed evenly over the eggs. This is accomplished by sifting the salt through a fine sieve, over the egg mass, using about 1 pound of Luneberg or Russian salt or ½ pound mild-cure or packers fine salt to 12½ pounds of roe. The New York caviar firms differ as to the amount of salt they believe is necessary. They give amounts ranging from 5 to 13 pounds of Luneberg salt to each 100 pounds of roe. Users of American dairy or mild-cure salt are advised to add 4 pounds of salt only to 100 pounds of roe by one caviar merchant and are told that more than this will give a "woody" taste to the caviar. Another advises the use of the same amount of mild-cure salt as of Luneberg salt. It is agreed that the cure should be mild as heavily cured roe will sell only to the cheapest trade, and that the amount of salt needed will vary according to the condition of the roe, the season (less salt is needed in cold weather), shipping conditions, and the species of sturgeon used. The amount of American dairy or mild-cure salt should be consistently somewhat less than the European salt since the former contains less chemical impurities and, therefore, penetrates more rapidly. European references commonly give 8 pounds of salt per 100 pounds of roe as an all around average (Hoffman (undated) and Jacobsen 1926).

As soon as the required amount of salt has been added, eggs and salt should be thoroughly mixed by hand. Paddles or other stirring utensils are not recommended. The process of stirring is the most delicate operation in curing caviar. Only trained men of much experience can do it really well, avoiding unnecessary breakage of eggs and securing an even blend of eggs and salt. At first the egg mass will be sticky but a brine is soon formed by the strong attraction of the salt for the liquid content of the eggs. Cobb (1919) stated that both hands should be used to mix the eggs and salt thoroughly for 5 to 8 minutes until foam or slime appeared on top of the egg mass. The mass is allowed to stand for about 10 minutes and is then mixed again. By this time a copious brine should have formed, so that the eggs will pour readily. If the operation has been properly performed a slight noise is perceptible when the mass is stirred, like small pieces of glass rubbing against one another.

The salted eggs are transferred to trays with a fine wire-mesh bottom ($\frac{1}{32}$-inch mesh) holding about 10 pounds each. These trays are placed between cleats on slanting boards set against a wall. They remain here until the brine is completely drained away. Sufficiency of drainage is determined by pressing against the underside of a tray at a single point. If the mass cracks open, the cure is completed and the mass may be removed. The time required for drainage is reported to vary from 2 to 4 hours. Good draining is very important, for if the caviar is "soupy" when received by the dealer it must be drained again, and the resulting loss in weight is charged against the shipper.

Radcliffe (1925) reports that:

> The impression of some fishermen that the more salt added the heavier will be the caviar is wrong. The addition of salt extracts the water from the eggs and reduces their weight. For the caviar to retain its delicious flavor the roe must be mildly cured. If an excess of salt has been used, the caviar on being treated by the canners will taste so strongly of salt as to be practically unsalable. The only changes in the amount of salt depend upon temperature conditions. In cold weather as little as one pound of the Luneberg salt or one-half pound of the dairy salt to 18 pounds of roe may be sufficient, but in very warm weather as high as one pound of the Luneberg salt or one-half pound of the dairy salt to 9 pounds of roe may be required. If the roe is too ripe, and the entire egg mass is soft and tender to the touch, it may be put into a strong brine until it is thoroughly "struck" with salt. This, however, makes an inferior grade of caviar.

The sturgeon caviar is packed in small kegs to a net weight of 100 pounds. If the total amount to be shipped is less than this weight, wooden tubs or "kits," or large tin cans with tightly fitting covers may be used. Some curers line the containers with vegetable parchment paper before filling. The caviar should not be dipped out of the sieves in filling. Turn the sieve upside down over the shipping container and allow the contents of the sieve to fall out in a mass. The containers are not headed immediately but set in a cool place to stand for a few days until the caviar has settled. The head space thus formed is filled with caviar so that no air space is left, the top is fixed on tightly, and the container is ready for shipment. If possible, light and dark colored roe should be cured and packaged separately. Mixing the two colors gives the product a speckled appearance, making it less valuable than caviar of uniform color. Under no circumstances should any chemical preservative be used.

The caviar may be sold to wholesale dealers in the locality who in turn resell to the packers and distributors of caviar in New York. Of recent years, however, some fishermen curers have been dealing directly with the New York packers. Caviar should be shipped and held in chill storage at 34° to 36° F. If the curer does not have refrigerated shipping facilities the container should be placed in large barrels or boxes and surrounded with ice.

When packaged for the United States retail trade, caviar is filled into cans holding 1½ to 2, 4, and 8 ounces or into nappy glass containers holding about the same amount. Occasionally 1- and 2-pound containers are used, mostly for the hotel trade.

Caviar Industry of the U. S. S. R.

The U. S. S. R. has the most important caviar industry in the world and has devoted special study to the technology of caviar preparation and storage. The Caspian Sea is the only body of water in the world today where sturgeon are still to be found in large numbers. Fairly important amounts of sturgeon are also taken in the Black Sea, Sea of Azof, and in the rivers of the Ural region, according to Lazarevsky (Kasatkin 1940). The U. S. S. R. accounts for from 92 to 95 percent of the world sturgeon catch. Lazarevsky gives the U. S. S. R. production of various types of caviar in 1937 as: salmon caviar, 23,800 centners (5,236,000 lbs.) or 46 percent of the total; miscellaneous fish, 18,800 centners (4,136,000 lbs.) or 38 percent; and sturgeon, 1,600 centners (352,000 lbs.) or 8.2 percent of the total. Although the amount of sturgeon caviar is the smallest of the different varieties, it is the most important in world trade, and its value exceeds that of salmon and miscellaneous types of caviar. It is also regarded as the highest in quality.

The caviar industry of southern Russia is based on 4 species of sturgeon. They are beluga, schip, ossiotr, and sevruga. The beluga (*Huso huso*) is the largest species and supplies the highest grade caviar. Beluga sturgeon usually weigh from 110 to 130 kilograms (242 to 286 lb.), and produce from 15 to 20 kilograms (33 to 44 lb.) of caviar. Occasionally a catch is made of a beluga weighing as much as 1,000 kilograms (2,200 lb.) and containing as much as 160 kilograms (352 lb.) of caviar.

The schip (*Acipenser nudiventris*) and ossiotr (*A. guldenstadi*) sturgeon usually weigh from 15 to 80 kilograms (33 to 176 lb.) and produce from 2 to 12 kilograms (4.4 to 26.5 lb.) of caviar. The sevruga (*A. stellatus*) is the smallest of the sturgeons but is the most plentiful. It weighs from 12 to 50 kilograms (26.4 to 110.0 lb.) and produces from 1 to 5 kilograms (2.2 to 11.0 lb.) of caviar.

Sturgeon fishing may be carried on over most of the year with the exception of the legally established closed season, which is usually June and July. The season is at its peak in April and May, when the fish are just approaching spawning condition and come in to fresh water where they spawn among the reed covered flats of the river mouths.

The sturgeon roe is most desirable for caviar at this time. There are two general types of sturgeon fisheries, salt and fresh water. In the shallower waters of the Caspian Sea a variety of set line or trot line is the most important type of fishing gear. These lines are often more than a kilometer (five-eighths mile) in length. The ground line is fastened to stakes driven into the bottom at each end. Hooks hang at the end of short lines fixed to the ground line at intervals. The hooks usually hang about 1 meter (3.3 ft.) below the surface, and are supported by cork floats. Gill nets are also used in the salt-water sturgeon fisheries and in some instances hand-lines. In the fresh-water sturgeon fisheries the haul seine is the most important type of gear, followed by the set line.

The fish are taken to a processing plant where the bellies are split open and the roe is removed. Great care must be taken to avoid contamination of the roe at this time. After removing, the roe is immediately rubbed through a "string" or metal sieve (fig. 26). This has a mesh large enough to permit the eggs to pass through without breaking but to retain tissue membranes. The eggs fall into metal pans below the screen.

Table 1.—Raw material requirements in preparing sturgeon caviar (Kasatkin 1944)

Qualitative factors	Grades, finished product			
	Extra	Highest	First	Second
Degree of ripeness	Ripe	Ripe	Ripe	Not quite ripe roe permissible.
Elasticity of egg membranes	Firm	Firm	Firm	Slightly weakened membranes permissible.
Size of grain	Large and medium		All sizes including small.	
Color [1]	Light gray, gray and dark gray.		Light gray, gray, dark gray and black.	
Natural flavor	None	None	Very slight "grassy" flavor, permissible.	Natural flavors permissible.

[1] In all grades of sturgeon caviar, yellowish and brownish colors are allowed.

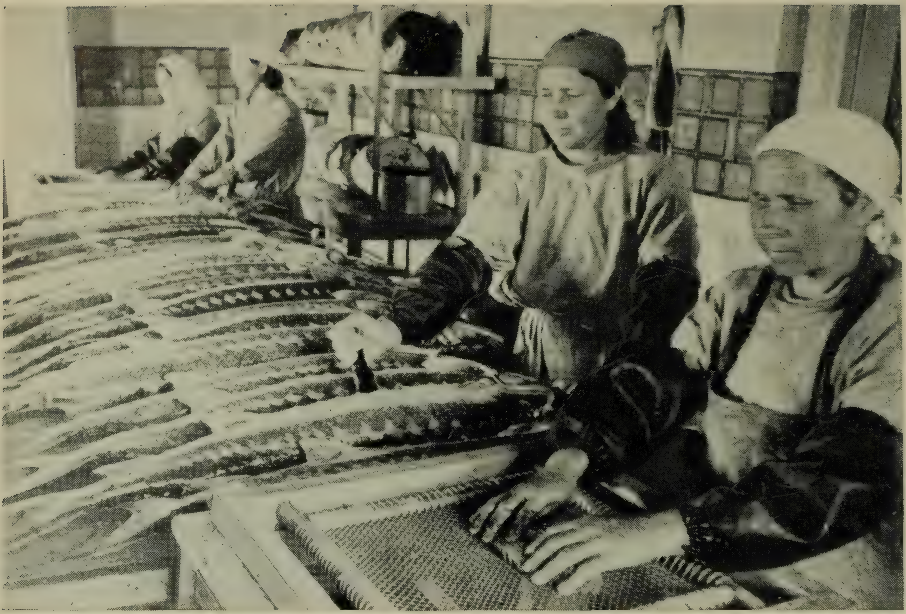

Figure 26.—The Russian caviar industry, showing the butchering of sturgeon to remove roe and the rubbing of roe on screen to separate individual eggs from the membrane.

The caviar is graded while it is raw, after being pressed through a sieve. It is graded first as to species, then as to the size of the eggs, their freshness, color, and flavor, their degree of ripeness, and the elasticity of the outer wall of the eggs. Grading is not exact and no two references agree. The most authoritative and recent is given by Lazarevsky (Kasatkin 1940). The data in table 1 taken from Lazarevsky, showing the requirements of raw material for grain caviar in jars, indicates the grades and factors involved in grading in the preparation of sturgeon caviar.

Unlike the German and American methods of preparing caviar, in the U. S. S. R. sturgeon eggs are washed before salting, except caviar that is prepared in strong brine, and packed in barrels. The eggs are washed in a pan with a perforated bottom through which water is forced. The water overflows, carrying off waste material. The loss in washing is usually from 1 to 3 percent of the original weight. When the surplus moisture is removed, the caviar is ready for salting.

The caviar is salted in pans. To obtain uniform distribution, salt is scattered over the caviar by shaking it through a sieve with 1 millimeter (0.059-inch) meshes. If chemical preservatives are to be used they are added at this time, mixed with the salt. Preservatives are added to all caviar packed in jars (except the grade "extra") as the preservative action of salt in concentrations from 3 to 5 percent is insufficient. According to the Institute of Fishery Technology in Moscow, the following mixtures of preservatives and salt have been used in the preparation of caviar:

Table 2.—Use of preservatives in caviar (Kasatkin 1944) [1]

Dosage of salt in percentage of raw material	Preservative	Dosage of preservative in percentage of raw material
4.5 to 5.0	Borax	0. 5
	Borax and boric acid	0. 5 (1:1)
	Borax and urotropin	0. 6 (5:1)
	Sodium fluoride	0. 1–0. 2
	Sodium fluoride and urotropin	0.2–0.3 (1:1)
	Animalin [2]	0. 2–0. 5
	Solution of formaldehyde	0. 2–0. 3

[1] Table 8 in The Production of Caviar by A. A. Lazarevsky translated by Paul S. Galtsoff.

[2] Mixture of sodium benzoate with urotropin and sodium citrate. Sodium fluoride should be excluded from the list as a strong antiseptic with considerable toxicity.

The sturgeon eggs and salt are carefully mixed by hand. Sufficient salt is absorbed in from two to three minutes, depending on the quality of raw material, the temperature, and the quality and quantity of salt used. Sufficiency of salting is determined by the change in the appearance of the grains or individual eggs and the amount and consistency of the liquid formed. The excess liquid is separated from the caviar by pouring the contents of the pan over a sieve, which is shaken carefully. When properly salted the grains are globular and elastic because of swelling of the eggs and hardening of the membranes.

When salt is mixed with the eggs the moisture that is extracted dissolves the salt and forms a liquid. At the same time certain amounts of soluble protein are extracted. By the end of the process, when using a 4 percent concentration of salt, each 100 grams (3.57 oz.) of raw caviar, yields 4 cubic centimeters (0.135 oz.) of liquid, which contains 13 percent salt and from 13.5 to 14.0 percent dry matter, the latter including from 0.5 to 1.0 percent of substances extracted from caviar.

The quality of salt affects the processing as well as the flavor of caviar. The salt should be as free as possible from chemical and mechanical impurities. It should pass through a sieve with a mesh of one millimeter square without leaving a residue. Impurities, expressed in ions should not exceed: Cu. 0.05 percent; Mg. 0.02 percent; So. 0.40 percent, and Cl. content should not be less than 60.33 percent of dry salt. Insoluble residue should not exceed 0.05 percent and moisture should not be in excess of 0.5 percent.

In curing, caviar salting should be stopped when the maximum amount of moisture has been formed, but before any appreciable amount of soluble protein is extracted. This gives a product of maximum dryness with grains that are easily separated. Caviar made in this way is called "dry" or "grainy," as against "liquid" or "under-processed" and "thick" or "over-processed." In the first case, salting was stopped too soon and not enough moisture was extracted from the caviar. In the second case, the extraction of soluble protein went too far and the liquid was not sufficiently removed; it forms a thick mass which fills the spaces between the separate grains.

The effect of the length of salting time on the amount of liquid and its salt concentration of extracted substances is shown in table 3. The salt content of the liquid is decreased, while that of the caviar is increased.

Table 3.—Effect of salting time on amount of liquid and salt concentration (Kasatkin 1944)

Dosage of salt without preservative	Length of salting	Liquid formed per 100 gm. of caviar	Salt in liquid	Salt in caviar	Substances extracted from caviar
Percent	*Minutes*	*Centimeters*	*Percent*	*Percent*	*Percent*
4.0	1.5	4.16	13.31	3.68	0.44
---------	2.5	3.47	12.08	3.83	1.52
---------	5.0	2.45	8.90	4.03	----------

As soon as possible the caviar is removed from the sieves and packed in jars. The jars are slightly overfilled, the covers are pressed on, and the containers are set aside to allow additional free liquid to run off. The jars are set one on top of the other not more than six high, and their positions are reversed periodically. The liquid stops running in approximately one hour. The covers are then forced down until they are in the proper place, care being taken not to leave an air space between the caviar and the lid of the container. The jars are next wiped with a towel and rubber bands placed around the tops between the cover and the neck of the jar in order to prevent penetration of air and moisture within the container. The sealed and cleaned jars are immediately taken to a refrigeration room for storage.

Grain Caviar in Barrels

Grain caviar in barrels is prepared when weather conditions do not permit packing of very lightly salted caviar in jars; when a more durable product is desired, as for export, or where refrigeration is lacking for shipment and storage. Grain caviar in barrels is also cured when the quality of raw material does not meet the requirements for caviar in jars. The quality requirements for grain caviar in barrels are less strict than for caviar in jars. There are three grades of the finished product, "highest," "first," and "second." Only three quality factors are recognized in grading. First, the degree of ripeness. This is the same for all three grades and simply requires that the eggs must not be over-ripe. The second factor is the size and color of the eggs. For the highest grade there should be little difference in size and color. For the "first" grade, eggs of the nearest colors or sizes can be mixed; that is, light gray with gray, large grain with medium. There are no size and color standards for "second" grade. The third factor is flavor. Muddy and grassy, or so-called natural flavors, are not permitted in any of the three grades.

The method of preparation of grain caviar in barrels is the same as for that in jars, except that the caviar in barrels is more heavily salted. The amount of salt used for this product varies from 7.5 to 10 percent of the weight of raw material depending on the location, season of the year, and quality of the product. Length of salting is from 5 to 8 minutes, the variation factors being the same as for the amount of salt. The caviar is allowed to drain on wire-mesh screens for a longer time than that to be packed in jars. Surplus moisture must be more completely removed. Draining requires a period of from 2 to 4 hours. When sufficiently drained, it is packed in barrels lined with a linen cloth or parchment paper. The barrels are set in chill storage for 24 to 48 hours to allow the caviar to settle, so that there are no air spaces. The barrels are then filled, headed, and shipped. While more durable than caviar in jars, it requires refrigeration at all times.

Pressed Caviar

The consumption of pressed caviar is confined largely to the domestic market, though some was exported to England before World War II. The Russian name for pressed caviar is "páyusnaya." Pressed caviar should be uniformly dark in color and soft in texture. The salt content should not be higher than 7 percent and moisture should not exceed 40 percent. The flavor should be pleasant, without bitterness or excessive sharpness, and there should be no "off" odor.

The first steps in making pressed caviar are identical with the preparation of grain caviar. The roe is rubbed through a metal screen to separate the individual eggs from the membrane. The eggs are then placed immediately in strong brine, without washing. Just before using, the brine is heated to a point where the temperature will vary between 40° and 42° C. (104.0° and 107.6° F.) after the eggs are added. The density of the brine should be 1.192 at 40° C. The quantity of brine should be four or five times that of the weight of the caviar to be salted. In order to prevent the brine from being weakened below the optimum point, a thin layer of large salt crystals is placed on the bottom of the tank.

The raw caviar is added to the concentrated brine and stirred gently. The length of the brining period depends on the quality and quantity of the raw material in a batch and the temperature of the brine solution but it should not exceed 2½ and may be only 2 minutes. Sufficiency of salting is determined by observing the grains, which should be firm but not shrunken. When rubbed together they should grate like glass beads.

When the caviar is sufficiently salted it is scooped up in a sieve and packed in a long linen bag, which is then placed under a press. The degree of pressing is determined by the packer, depending on the size of the bag and the consistency desired in the finished product. When sufficiently pressed the caviar is removed from the press and is allowed to stand for 2 or 3 hours to permit cooling and uniform penetration of salt. Since all operations should be carried out as quickly as possible, especially the removal of the caviar from the brine, the amount of raw caviar in any one batch should not exceed 25 kilograms (55 lb.). When the pressed caviar has stood long enough it is packed in shipping containers.

Pressed caviar is packed in oak barrels lined with linen and parchment, or in cans. Barrels used are of 50 kilogram (110 lb.) capacity and are reinforced with iron hoops. It is important to leave no air spaces in packing. The cans used are of the so-called sanitary type. They are lined with parchment and are hermetically sealed. The loss in pressing and packing pressed caviar averages 22 percent. Pressed caviar is somewhat more durable than grain caviar but should be kept under refrigeration.

Pasteurized Grain Caviar

Caviar is pasteurized to obtain the maximum length of preservation. It is not considered as high in quality as fresh grain caviar and is intended for export, or use where refrigeration is not available. The original cure differs slightly from that for fresh grain caviar. The eggs are mixed with salt, then placed in a sieve as soon as the salt is dissolved. The brine formed by the salt in extracting liquid from the eggs is not poured off carefully as in packing fresh grain caviar and the caviar in brine is packed immediately into the containers. These are usually cans with a net capacity of 250 grams (9 oz.) and are inside enameled. Only dry, sterilized salt is used for curing the caviar.

A split-process pasteurization is given. The cans are processed for 90 minutes at 60° to 65° C. (140° to 149° F.). They are then cooled for 5 to 15 minutes, to 20° to 30° C. (68° to 86° F.) by a water spray and are then held for 24 hours at a temperature of 24° C. (73° F.). The pasteurization is repeated for a second and third time, following the same procedure. The cans are then washed, dried, labeled and packed in boxes. No chemical preservatives are used in the preparation of pasteurized caviar. Length of preservation is not indefinite, but the product will keep for several months at room temperature. If held at low temperatures, about 10° C. (50° F.) or less, it will remain in good condition for more than a year.

Cod Caviar

Cod roe is frequently made into caviar in the northern European countries to fill the demand for a lower-priced caviar. Cod roe is also occasionally made into caviar in the United States, especially for sale in the Boston, New York, and Philadelphia areas. This is done when other caviar is especially high-priced and scarce. There are several methods, of which the following is typical.

The fresh cod roe is freed from

all bits of gall bags or viscera, discarding any dark or bloody roe. The roe is then mixed with 20 percent of its weight in salt and packed in barrels. The barrels are filled with an 80° salinometer brine, as the roe must be entirely covered at all times. If this is not done oxidation occurs during salting, giving the caviar an "off" flavor. The barrels are examined occasionally to determine the condition of the roe. When the salt has penetrated entirely through the roe, and it is completely cured, it is ready for manufacture into caviar.

The salted roe is drained and placed in new tubs where it is soaked in pure fresh water, preferably flowing, to remove the excess salt. If flowing water is not used, the water should be changed two or three times. From 6 to 10 hours are required for freshening. The roe is then put through a grinder after which it is mixed with water. The bits of membrane float to the top and are skimmed off. As an alternative, the lobes may be rubbed over a sieve, the roe passing through and the bits of membrane and other offal remaining.

Any bitter flavors may now be removed from the cod roe by placing it in a tub and covering with a sodium carbonate solution, made in the proportions of 98 liters (25.9 gal. U. S.) of water to 2.2 kilograms (4.8 lb.) of sodium carbonate. The roe is churned in this solution in which it is then allowed to stand for 15 hours. The roe is then filled into a bag which is hung up and left to drain. While it is in the bag the roe is washed several times in clear, fresh water. The roe should be sufficiently freed from sodium carbonate so that the drainage water does not taste alkaline.

The next step is coloring. To 1.5 kilograms (3.3 lb.) of pulverized gelatin which have been soaked in 80 liters (21.1 gal. U. S.) of water, are added 78 liters, (20.6 gal. U. S.) of hot water, stirring steadily until the gelatin is dissolved. When the temperature has dropped below 25° C. (77° F.), 1 kilogram (2.2 lb.) of sodium benzoate and 400 grams (14.3 oz.) of black dye are added. In some instances the benzoate is not added. Its use is not legal in the United States. The dye sometimes has a lamp-black base. Enough of this solution to completely cover the roe is poured over it and the roe is mixed thoroughly with the coloring solution. It is then allowed to stand in the coloring solution for 6 hours. At the end of this time the caviar is removed from the solution. It is understood that some packers mix lampblack or lampblack and caramel directly with the roe. This method requires much less time.

When it is colored, the caviar is aromatized or flavored with two solutions. The first is made by grating the yellow peel of lemons, which is then covered with 60 percent grain alcohol. After standing for about 10 days, when the flavor has been thoroughly extracted from the peel, the solution is filtered. Small amounts of the extract are mixed with the caviar to taste. The second solution is made in the proportions of 500 grams (1.1 lb.) each of cloves, allspice, and coriander, and 250 grams (9 oz.) each of mace and ginger. These spices are pulverized and covered with 25 liters (6.6 gal.) of 30 percent alcohol. After macerating in the alcohol for several days, the spices are filtered out and the extract is added to the caviar in small amounts to taste, a few drops at a tims.

At this time some of the packers who do not use the dye bath method of coloring add sodium benzoate, in the proportion of 200 grams (7.14 oz.) of benzoate to 100 kilograms (220 lb.) of caviar. Boric acid is also used in addition to the sodium benzoate in the coloring solution by some packers. Urotropin (hexymethylamintetramin) is reported to be used by some European packers. This preservative is prohibited under the U. S. Food, Drug and Cosmetic Act.

The caviar is then packed in small vacuum-sealed glass tumblers holding from 2 to 8 ounces and in cans holding up to 1 or sometimes 2 pounds. It is not heat-processed and should be kept under refrigeration for maximum preservation. Jacobsen (1926) gives a number of methods for making caviar from cod roe.

Cod Roe Salted and Smoked

Norwegian cod roe is obtained mostly in the Lofoten winter fisheries, where salted and smoked caviar is reported to be prepared as follows. The whole lobes of roe, fresh and in good condition, neither too ripe nor green, are cleaned of all slime, blood, bits of gall bag, and other offal. After being washed in sea water and drained for a few minutes, the roe are salted down in barrels. The roe must be salted whole without injuring or breaking the enclosing membrane, and must not be salted too much, just sufficiently to keep them from decomposing and to give them an orange-red color. The amount of salt used is believed to average about 10 pounds per 100 pounds of roe. When the roes are cured, that is, when they have acquired the desired color, they are removed and washed thoroughly in sea water (although Stevenson says fresh water) several times. The roes are then hung out in the air on wires or drying racks, protected from the direct rays of the sun if it is bright. After drying about 24 hours, when no surface moisture is apparent and they feel dry to the touch, the roes are ready for smoking.

The roes are hung in the smokehouse on sticks, like fillets, or are laid on trays with wire-mesh bottoms, and cold smoked for 2 or 3 days until they acquire a dark-brown color. After smoking, the enveloping membrane or skin of each roe sac is split and removed from the lobe. The mass of separate eggs is then packed in barrels which are then tightly closed and placed in a normally cool place (about 55° to 60° F.), for a month or 6 weeks. At the end of that time fermentation should set in, which may be determined by the swelling of the barrel. The barrels should be watched closely during this period or fermentation may set in and progress too far before it is detected. As soon as it is determined that fermentation has begun, enough salt to arrest fermentation should be mixed through the roe. This is estimated at about 15 pounds per 100 pounds of roe.

Through the fermentation the roe is given a slight acid flavor and a taste resembling that of fermenting beer or wine, which must be stopped by adding salt at a certain point in the process, to be determined only through experience. The salt used to arrest fermentation must be fine and of the best quality. If the roe seems too dry, enough olive oil is added to moisten the product. After the roe has been thoroughly mixed with salt it is packed in tin containers, hermetically sealed but not processed. The usual size is a ¼ round tin with a net weight of about 3¾ ounces. Glass jars are also used in the ¼ size, with the same net weight.

Mullet Roe

From 80,000 to 150,000 pounds of dry-salted mullet roe are prepared commercially each year in the United States. This product is also cured in the Mediterranean area and in portions of the Soviet Union. Recent data on production in Europe are not available but it is believed that the pack of dry-salted mullet roe is larger than in the United States, where commercial preparation is divided between North Carolina and Florida. Cured mullet roe is a byproduct of mullet salting and fresh-mullet filleting in the south Atlantic and Gulf Coast States.

The quality requirements of the raw material are the same for the two methods of dry-salting followed here. That is, the roe must be fresh, of good color, and the skin of the roe sac must not be broken. The roe must not be over-ripe nor should it be too green or underdeveloped.

In both methods the first step is to prepare the roe by freeing the lobes from blood, gall bags, bits of intestine, and black skin. After being washed thoroughly and allowed to drain, they are ready for salting.

Dry-Salting Mullet Roe

In the first method, after this preliminary treatment, the lobes of roe are rolled in fine salt. As a rule, 2 pounds of salt to 10 pounds of roe are sufficient. Too much salt must not be used as an excess will break the egg sacs. The lobes are picked up with as much salt as will cling and packed in tubs or boxes, with a scattering of salt over each layer. They remain in salt for at least 48 hours and may then be placed in chill storage and held in salt for some time if not marketed immediately. Sometimes salted-mullet roe is held in dry salt at room temperature. In packing for sale, it is taken out of salt and placed in fillet boxes with a light scattering of fresh salt. The consumer freshens the roe to suit the individual taste.

Air-Dried and Pressed Mullet Roe

In the second method the washed and drained lobes of roe are rolled in fine salt, using about 1 pound of salt to 10 pounds of roe. The lobes are removed from the salt in from 6 to 12 hours and are brushed well to remove any traces of excess salt. They are laid out to dry in direct sunlight, usually on a shed roof. During the first day of drying, the lobes of mullet roe are turned at least every hour and in the evening are brought indoors. Any night moisture such as dew, fog or rain falling on the roe after drying has started will spoil or at least damage the product. Boards and weights are placed on the roes during the first night or two in order to compress them slightly. Curing requires about one week under good drying conditions. Drying is completed when the roe is reddish-brown in color and feels hard. The thumb should make no impression. The dried roe is usually dipped in melted beeswax which acts as a protective covering and is recommended as an additional aid in preservation.

After being allowed to cool for about 15 minutes the roe is wrapped in waxed paper, packed in wooden or tin boxes and stored in a cool, dry place. The product is sliced thin and eaten as an appetizer without further preparation.

This method of preparing roe is believed to have been introduced into the United States in colonial times by Englishmen who discovered it in Greece. Mullet roe, salted and dried according to this method, was well liked in England during the 17th century when it was called "bolargo." It is mentioned in Pepys' "Diary." Dried mullet roe is sometimes known as "botarque" in the Mediterranean area.

Salmon Caviar

Salmon caviar was originated about 1910 by a fisherman in the Maritime Provinces of Siberia, and the preparation is a modification of the sturgeon caviar method (Cobb 1919). Salmon caviar has found a good market in the U. S. S. R. and other European countries, where it is known as "red caviar" to distinguish it from the sturgeon or "black caviar." Although several attempts have been made to manufacture salmon caviar in the United States, only a few firms in the Pacific Northwest have operated successfully on a commercial scale. Their product is marketed mostly in New York and other eastern cities. A salmon-canning firm operating in the Bristol Bay area of Alaska also prepares salmon caviar, principally for export.

To be suitable for caviar, the salmon eggs must be absolutely fresh, free from blood, and of clear color and good consistency. Large eggs do not make good caviar. Most salmon caviar is prepared from the roe of silver and chum salmon, which have been found best suited for the purpose (Jarvis 1935).

The egg sac is split and rubbed gently over a table stand with a top of half-inch mesh screen. This mesh is just large enough to let the eggs drop through, separating them from the membrane. The eggs fall onto an inclined screen of fine-wire mesh leading into a large shallow box. The eggs drain on the screen and finally slide into the box. The eggs are cured in brine testing 90° salinometer, usually made from fine mild-cure salt. The salmon eggs are stirred occasionally with a wooden paddle to insure thorough mixing and equal absorption of brine. The brining time varies with season, temperature, and humidity, besides size, consistency, and freshness of the eggs. The time required varies from 15 to 30 minutes. The packers determine the sufficiency of cure by noting the change in consistency of the eggs. The interior must coagulate to a certain jelly-like consistency but the eggs must not be shrunken. After brining, the eggs are dipped from the vat, placed on wire-meshed screens and drained overnight, or for a period of about 12 hours.

After draining, the eggs are filled into small kegs holding about 100 pounds and lined with vegetable parchment paper. The kegs are covered and allowed to stand until the eggs settle. The headspace caused by settling is then filled with more caviar, the kegs are headed, and put in chill storage at 34° to 36° F. until shipped. They are shipped under refrigeration.

The caviar is repacked in glass by large wholesale dealers in the eastern part of the United States. Nappy glass jars, holding 2 to 4 ounces are probably the most widely used containers. To obtain the maximum preservation the containers should be held at temperatures not higher than 40° F. or less than 29° F., which may keep the caviar in good condition for a year.

Salmon Caviar Russian Method

Chum and pink salmon are used most widely. Caviar may also be made from silver-salmon roe. Chinook salmon is not favored because of the large size of the eggs. The roe sacs are slit and rubbed over a screen to separate the eggs from the membranes. The eggs are then mixed in a concentrated salt brine (sp. gr. 1.200), previously boiled, and cooled to a temperature of from 13° to 18° C. (55.4° to 64.6° F.). The volume of brine should be three times that of caviar. Salt requirements are the same as for sturgeon caviar. The salting time varies as follows: In the Amur district, it is from 8 to 10 minutes for the best grade caviar; in the Kamchatka district, 12 to 14 minutes. For second grade caviar the time is 10 to 12 minutes in the Amur area, and 14 to 15 minutes in Kamchatka.

When sufficiently salted the caviar is allowed to stand for 12 hours to allow the brine to drain off and to permit uniform penetration of salt. Dry borax and urotropin are then added and distributed uniformly by mixing. Olive or cottonseed oil is added in small amounts and mixed with the caviar to prevent the grains from sticking and to give the product a more glossy, attractive appearance. The salmon caviar is then packed in barrels, which have been coated inside with a mixture of paraffin and wax, in equal parts. The sides and bottoms of the barrels are covered with parchment soaked in concentrated brine, then with cotton cloth impregnated with vegetable oil. Low-temperature storage is necessary for salmon caviar if it is to be preserved for any length of time.

Salmon Eggs for Bait

The first commercial use made of salmon roe was the preparation of bait eggs for catching trout and other game fish. This industry began about 45 years ago. A number of firms in the Columbia River and Puget Sound districts are now engaged in packing bait eggs and find a ready market for their product.

Each packer of bait eggs uses his own formula. The method described here is not used by all packers of bait eggs but has been used commercially and will at least serve as a basis for experimentation. The first steps in preparing bait eggs are almost identical with the first stages in the preparation of salmon caviar. The roe must be fresh and not too green; that is, the eggs must have a firm consistency and separate readily from the enclosing membrane. They must be of good size and clear in color. The egg sacs are split open and hot water is poured over the roe, which separates most of the eggs from the membrane and the remainder are freed by rubbing over a wire-mesh screen. This method is quicker than screening the entire mass but should not be used except by skilled bait-egg packers, as over-exposure to hot water will damage the texture of the eggs and make them unfit for use.

Single Eggs

After draining for a few minutes, the eggs are placed in a solution of salt, sugar, and coloring material. The proportion of salt to sugar varies with different packers and may range from 1 part sugar to 3 of salt, to 1 part sugar to 9 of salt. The coloring material used is one of the aniline dyes in several shades of red, such as Sherwin Williams 3R or Erythrosin. The curing solution will test 80° to 90° salinometer and eggs are left until "cured." The cured eggs must have a firm consistency so that they cannot be easily stripped from the hook but must not be shrunken, hard, or rubbery.

The color of the eggs depends on the strength of the dye and length of time the eggs are left in the dye-pickling brine. For a medium shade the eggs are left in the brine from 20 to 30 minutes. Some markets desire a brilliantly colored egg, while others require a pale shade resembling the natural color of the fresh egg. It has been the tendency among fishermen to insist that the first shade of color used for bait eggs in their district is the only one that will attract fish.

After the eggs are sufficiently colored and cured, they are drained on wire-mesh, screen-bottom trays and packed in small glass or tin containers. The most popular container is a glass jar with a two-piece screw top, holding 3½ ounces. The tin can most widely used is a lithographed container of the same net weight. Sometimes a solution of glycerine and preservative is added before sealing the containers but packers of bait eggs claim that if the eggs have been properly prepared, this should not be necessary. Bait eggs will remain in good condition for a year if kept in a cool, dry place. If the jar is opened, however, mold will start growing in a short time (Jarvis 1935).

A preservative, usually one percent sodium benzoate, is added to the curing solution if the eggs are to be sold in warm climates. Also, the glycerine solution may contain 5 to 10 percent formalin for maximum preservation. The eggs will harden and turn white if the formalin solution is too strong. Formaldehyde is legally prohibited for use as a bait-egg preservative in some localities on the belief that it is poisonous to fish life. There are no scientific data to support this theory.

Cluster Eggs

In addition to single eggs, "cluster eggs" are marketed. These are portions of roe with membrane and eggs adhering. They are used principally in fishing for steelhead trout. Cluster eggs are manufactured from small green roes, which are partially undeveloped. The clusters are washed, then placed in a brine as described in the preparation of single bait eggs. Preservatives, either formalin, hexymethylaminteramin (urotropin) or sodium benzoate are frequently added to this brine.

The time required for curing is variable and is determined by testing the consistency of the eggs. As a rule it is somewhat longer than that required for the preparation of single bait-eggs. When the pieces of roe are cured they are drained and packed dry in ½ or 1 pint glass jars. Under ordinary conditions of temperature and storage, "cluster" eggs will remain in good condition from 6 to 12 months.

Salted and Air-Dried Tuna Roe

Tuna roe is cured in southern Spain, in the Mediterranean area, especially on the Spanish coast, and to a lesser extent in French Africa. It is cured occasionally in our waters by foreign-born fishermen for home use but is not a commercial product in the United States.

Spent roe is not used for salting and drying. Only the roe of unspawned fish is desired. It should not be too small and unripe, nor be in the spawning stage. The roe is taken out of the tuna as soon as the fish are landed and should be prepared immediately. Great care must be taken in gutting so as not to damage the roe or taint it by breaking the gall bladder.

There is apparently some variation in the method of cure, according to locality (Dieuzeide and Novella 1942; Classen 1946; and Uriarte 1926). According to one source the tuna roe is washed when removed from the fish and allowed to drain for a few minutes. It is then put in a tank partly filled with saturated salt brine (100° salinometer or 25° B.). Additional salt is thrown in so that the brine will not be weakened too much by extraction of moisture. The roe is left there about 12 hours. It is then removed from the brine, rinsed, and wiped off with the hands. Then the lower part of each lobe is pierced with a knitting needle to allow the moisture to escape. The roes are then placed in rows on a marble slab sprinkled with three-quarter ground salt. Additional salt is scattered over the roes and a second marble slab set on top. After several hours, or, at the latest, the next morning, the roes are weighted down more heavily. Two days later the weights are removed, the roes are turned over, and the lower parts of the lobes are pierced again to allow the moisture in the tips to escape. After sprinkling with fine salt for the second time the roe is weighted down once more and allowed to stand 4 or 5 days.

The weights are then removed from the roes, which are rinsed quickly in a strong salt brine (almost saturated) and prepared for air drying. Two parallel slivers of cane are placed at the narrowest part of the lobes, where they grow together, and are tied. A loop of string is fastened to this frame, with a hook at the end of the loop so that the roes can be hung from a line for air drying. After drying in the shade for several days, the time varying according to temperature, humidity, air circulation, and size of roe, the roes are hard and reddish-brown in color. When brushed with olive oil, or coated with beeswax, they are ready for market (Dieuzeide and Novella 1942).

In Spain the salting and drying of tuna roe is more of a large-scale industry than in France. As soon as the roes are separated from the viscera of the tuna, they are sorted and graded. Only the large and medium roes are taken for curing. Small roes are canned.

The first step in preparation is to clean the roe. The oviduct and the big lump of adipose tissue adhering to the roe are cut off. The large vein is removed and the blood from the small veins is forced out by pressure from the blunt back of a knife blade. The lower end of each lobe is punctured in several places so that moisture may run off during the drying process. After washing thoroughly in sea water the roes are allowed to drain a few minutes, then salted down in kenches on the concrete floor of the fish house. Each roe must be completely covered with salt. The kenches are from 2 to 3 feet high. The tuna roe is left in salt from 24 to 36 hours. It is then taken out of the salt, rinsed in sea water and allowed to drain, then placed in rows on a large board that has been sprinkled with fine salt. The roe is sprinkled with salt, a board sprinkled with salt is placed on top, repeating until there is a stack of six or seven layers. The completed stack is set in a simple screw press with large cross beams and placed under light pressure.

Classen (1946) reports the following process:

> Every day the roes are taken out, rinsed with sea water, and the salt renewed (each day a lesser quantity of salt being used), and put again in the press with the pressure increased. After a week or so no salt is added and the pressure is again increased. After a few

more days (in all, the roe remains in the presses 9–10 days) the roe is finally taken out from the press, washed, and rubbed very thoroughly in fresh water with a hard fibre brush to remove any impurities, salt, and slime, and hung on the beams of the drying ground in the same way as mojama, in the shade of rush mats. The color of the roe changes during the drying process from pinkish-yellow to a deep red-brown on the outside and a rich orange color inside.

An average of 15 days is required to dry the roe. It is then taken down and packed in paper-lined wooden boxes, ready for shipment. Sufficiency of drying is tested by pressing the lobe between thumb and forefinger. When the thumb makes no impression, the cure is finished. Classen estimates the average weight of the roes before salting as 4 kilograms (8.8 lb.) a pair, and that in curing and drying they lose about 60 percent of their weight, so that a pair will have a dried-weight of approximately 1.6 kilograms (3.5 lb.).

Salted and dried tuna roe is regarded as an hors d'oeuvre of high quality. To serve, it is cut in thin slices and mixed with sliced onion and vinegar, or marinated in oil and vinegar.

Tuna Caviar

A paste made from small, deformed, or damaged tuna roes is reported to be sold commercially in Spain under the name of tuna caviar (Classen 1946). The method of preparation is as follows:

The roes are washed, split open, then boiled in a brine made in these proportions:

80 liters (84.5 qt.) water
2 kg. (4.4 lb.) salt
8 sliced peeled lemons
1 kilogram (2.2 lb.) sliced onions
8 bunches celery
10–12 large green Spanish peppers

Black peppers, garlic, bay leaves, to taste

The liquid is brought to a boil. The roes, in a wire basket, are immersed in the liquid. The pieces stick together very easily, causing uneven cooking, and therefore, must be stirred gently from time to time. If stirring is not done carefully many grains separate from the mass and are lost. When thoroughly cooked, about 20 minutes of simmering, the baskets are taken out and set aside to drain and cool. When the pieces are cool enough to handle, the eggs can be separated from the fibrous tissue in lumps without the use of a knife. The next step is to pass the eggs through a meat grinder, using the plate with smallest holes. The eggs now have a pinkish-yellow color. They must be handled immediately as they turn gray if left exposed to the air. The ground roe and other ingredients are placed in a mixing machine together with following:

30 kilograms (66 lb.) ground roe.
2500 grams. (5.6 lb.) lard
3600 grams (8 lb.) canned sweet peppers, ground
2500 grams (5.6 lb.) ground onions (fried golden brown in lard or oil)
0.9 liter (1 qt.) vinegar 2½ percent)
300 grams (11 oz.) salt
300 grams (11 oz.) sweet red pepper, ground (sweet paprika)
15 grams (0.5 oz.) ground cloves
45 grams (1.5 oz.) ground white pepper
3 liters (3.2 qt.) stock used in cooking roe, filtered

The ingredients are thoroughly mixed until a paste of satisfactory texture is obtained. The paste is filled immediately into size ⅛ cans with capacity of 100 grams (3½ oz.) net. The cans must be well filled, so that no air remains in the can, but care must be taken to avoid overfilling. The cans are sealed and heat processed. The process is 108° C. (266.4° F.) for 50 minutes.

Miscellaneous Caviar

Caviar is made from the roe of a number of fish besides those previously mentioned. In some parts of Europe the roe of carp, herring, perch-pike and other miscellaneous fish are made into caviar. In the United States some river herring or alewife roe is manufactured commercially as caviar. In fact, the roe of nearly all sea fish and many of the fresh-water fish is used if it is obtained in suitable condition. Nearly every curer has his own method and the preparation differs somewhat with different species. As the individual eggs of nearly all species are small there is no accurate gauge as to sufficiency of salting. Because the products must be rather heavily salted for long preservation, many of them are much too salty for the average American taste. A more careful control of salting would do much to improve the popularity of caviar in the United States market and promote the utilization of miscellaneous fish roe.

One of the European methods used in making caviar from the roe of herring, pike, and other miscellaneous fish is given below. If followed carefully the method may also be used with alewife roe in the United States. The fresh roe is cleaned carefully and freed of blood and slime. It is then rolled in fine salt and packed in barrels which are filled with strong salt brine and headed up. The roe is held in salt until it is to be made into caviar. The salted roe is then washed thoroughly in cold water to remove surplus salt and other extraneous material. A solution is made up in the proportion of 5 liters (5.3 qt.) of cold water in which is dissolved 50 grams (2.0 ounces) of borax to 10 pounds of roe. The herring roe is soaked in this solution for 24 hours. It may be changed once or twice during this time.

When the freshened roe has drained, the skin of the roe sac is split and the eggs are rubbed over a sieve with a ⅛-inch mesh. The eggs pass through while the skin and connective tissue are retained. The roe is again washed thoroughly then drained until it is free from water. The roe is then colored. The coloring material used is lampblack or lampblack and caramel. A mixture is made up in the proportion of 50 grams (2.0 oz.) of salt, 10 grams (⅜ oz.) of pulverized citric acid, and 10 drops of oil of lemon, to each 10 pounds of roe. The flavor is also improved if 100 grams (4.0 oz.) of olive oil is added. The mixture is stirred thoroughly into the roe. After standing 6 days, the caviar is ready for use. It is packed in vacuum-sealed glass tumblers with net weight of two and four ounces. The jars are not heat processed.

SMOKING FISH

Smoked fish has served as a staple food since the dawn of time. If an explanation of its origin were called for, it would have to be some legend such as Charles Lamb's story of the discovery of roast pig. In all probability the discovery of the use of smoke as a method of preserving flesh foods such as meat and fish was accidental. It was certainly discovered long before man had progressed beyond the Stone Age of existence. The logical deduction is that smoked fishery products are a natural development of drying. Smoke from the fire in the hut flavored dried fish hung from the rafters for storage. When the improvement in flavor and length of preservation were noted, smoking as a method of food preservation was developed. The commonly accepted story of the discovery of "finnan haddies" lends support to such a theory.

Though the quantity of smoked fish used, and the value, have increased, smoked fish has lost in relative importance to other fishery preparations as a food product in this country. The increase in value is due to the development of smoked salmon and a few other high-priced specialty products. The consumption of the lower priced standard products, most of them as appetizing as smoked salmon, has not increased appreciably. At one time such an article as hard-smoked or "red" herring was a staple article of food in the interior as well as along the seacoast. Now, smoked fish is bought as a regular article of diet only by some of the inhabitants of certain seacoast areas, or by immigrants who have not yet lost their taste for this product.

With better advertising and merchandising methods, backed by a carefully prepared product of standard quality, the smoked-fish trade of this country would be considerably increased. A few firms which are making efforts in this direction are marketing several types of smoked fish, formerly sold in bulk, in an attractively packaged form. The reception of such articles as selected bloaters, trimmed of head and tail and packed in cellophane wrappers, sliced smoked salmon packed with olive oil in quarter-oil sardine cans, in 4-ounce jars, and in packages of 1 to 8 ounces wrapped in cellophane, and choice kippered herring in cellophane envelopes is encouraging and indicates the possibilities for building up a good market for quality smoked fish.

The development of smoked fish as a packaged article should include a more extensive use of the glass container as well as cellophane or parchment paper. Glass has been used to some extent since the early nineteenth century but a systematic study on the wider application of glass jars as marketing containers for different varieties of smoked fish, accompanied by the proper merchandising, would undoubtedly increase the sale of smoked fish.

CHEMISTRY OF FISH SMOKING

Several studies have been made in recent years on the chemistry of wood smoke in curing fish. These studies are not yet complete and there is some disagreement as to results. On the basis of present knowledge, preservation in smoking depends principally on the removal of moisture by drying and salting or brining, rather than the inhibitive action of different volatile chemical substances given off in wood smoke. A number of investigators have published data indicating that wood smoke has some bactericidal effect. It would seem, however, that wood smoke is more valuable as a flavoring than a bactericidal agent. When it is desired to prepare a smoked fish with better keeping qualities than the average, the salting and smoking are done very thoroughly. Rector (1925) believes that with fish the preliminary salt treatment is even more important since it helps in the preservation and at the same time makes the fish firmer by drawing out large quantities of water.

The preservation action of wood smoke has generally been held to be largely due to the presence of a number of phenolic compounds classified under the wood-creosote group. In regard to this, Tressler (1923) states that the wood creosote constituents as determined in the products of wood distillation are the xylenols, guaiacol, creosol, and other methyl esters of higher phenols. There is also, possibly, a very small amount of lower phenols such as creosol and phenol, but they are thought to be present in very small quantities. The number of organic compounds occurring in wood smoke is very great and there may be other compounds deposited on the fish which also have a powerful preservative action. Some of the other organic compounds produced in wood smoke are formaldehyde, acetic acid, acetone, and methyl (wood) alcohol.

An important and interesting contribution to the chemistry of fish smoking has been made by Hess (1929) in a study of the bactericidal effect of smoke in fish curing. He believes that formaldehyde is an important disinfecting constituent of smoke. He finds little difference in the bactericidal effect of smoke from different sources, such as hardwood sawdust, softwood sawdust, or a mixture of both. Dense wood smoke was found to contain a higher concentration of preservative or disinfecting agents than a light smoke. Griffiths and Lemon (1934), in a study on the smoking of haddock, included a determination of the effect of formaldehyde in the preservative action of wood smoke. As a result of their experiments they came to the conclusion that though formaldehyde is found to be present in small quantities in wood smoke and smoked fish, and in the destructive distillation of sawdust, it has no significant preservative action in cold-smoking fish.

Liquid Smoke and Other Chemical Preparations

The use of chemical agents such as liquid smoke or of salt impregnated with chemicals found in wood smoke has been advocated as a substitute for smoking. It is claimed that smoke flavor is better controlled, flavor is improved, greater length of preservation is secured, the time required for curing is greatly reduced, and that the smokehouse may be eliminated. These agents have been found useful in meat curing, where they seem satisfactory, especially for non-commercial use. Experimental packs of fish using liquid smoke and two varieties of "smoked salt," that is, fish salt impregnated with the products of combustion of some one of the woods used in the smoking of fish or meat, were made at the laboratories of the College of Fisheries, University of Washington, and the U. S. Fish and Wildlife Service. The conclusion was reached that the appearance, texture, and flavor were not equal to that of fish smoked by common methods. It was also believed that while liquid smoke and smoked salt might be used as a flavoring in some types of canned fish or in the preparation of fish fillets, they are not a satisfactory substitute for the smokehouse.

Chemical Preservatives for Smoked Fish

It must be remembered that preservation by smoke-curing is temporary, the fish remaining in good condition for only a comparatively short period. Smoked fish is subject to mold or bacterial spoilage within a short time unless it is held at a low temperature. Attempts to inhibit spoilage by the addition of chemical preservatives have been made with more or less success. The preservative is sometimes added to the brine used in salting the fish preparatory to smoking. At other times preservatives are dusted over the smoked fish. The use of these substances is not advisable. Original inferior quality is too easily masked by the use of chemical preservatives. Then too, regulations governing the use of chemical preservatives in food are becoming more stringent as knowledge of their effect has accumulated. Sodium benzoate is one of the few preservatives permissible under United States law. It may be used in amounts not greater than $\frac{1}{10}$ percent and its presence and amount must be stated on the label, with directions for its removal. Other preservatives that have been used in the preparation of smoked fish are mixtures of boric acid, salicylic acid, and salt. The use of these preservatives is now prohibited under the United States Food, Drug and Cosmetic Act.

General Methods

There are two general methods of smoking fish: cold-smoking or light-smoking, and hot-smoking or barbecuing. The products obtained by these two methods are different. Neither can be recommended over the other. Cold smoking is the most important method in the United States, Canada, the British Isles, and Norway. Hot smoking is used most widely in Denmark, Germany, and Sweden.

In cold smoking, the fish are hung at some distance from a low smouldering fire and are smoked at a temperature usually lower than 80° F. In curing a few products the temperature may be as high as 90° F. but never more than 100° F. The degree of preservation depends on the length of time the fish are smoked. Fish cold-smoked a few hours, for example, will keep only a short time, not much longer than fresh fish; finnan haddie and kippered herring are examples. If an extended period of preservation is desired, the fish must be smoked for several days up to 2 or 3 weeks. Hard-smoked or red herring is an example of cold-smoked fish which may be held for a long time. In hot smoking or barbecuing the fish are only a short distance from the fire, and are wholly or partially cooked. The temperature in hot smoking will vary from 150° to 250° F. The cure is completed in a few hours, usually not more than 3 or 4, and sometimes only 2 hours. Hot smoking arrests deterioration temporarily since the enzymes causing autolysis of the flesh are destroyed by the heat of cooking. Hot-smoked fish is ready for consumption when cured, requiring no further cooking. In the United States, hot smoking is used less than cold smoking. It is used principally for preparing kippered salmon and sablefish on the Pacific coast, smoked whitefish in the Great Lakes area, and for smoked eels and sturgeon in the North Atlantic coastal area.

Dressing or Preparation for Smoking

Fish may be smoked either round, gibbed (gills and part of viscera removed through a small opening at the throat), gutted, split, in fillets, or cut into small pieces. The skin may or may not be removed, depending on the product and on individual preference. Small fish are usually smoked round. Alewives and herring, except for kippers, and some lots of large herring, which are gibbed, are usually not dressed at all. Lake herring, eels, whitefish, and flounders are usually cut down the belly to the vent and gutted, but the head is retained. Haddock and mackerel (both Boston and Spanish) are split so that they will open in one piece. Cod and some large haddock are cut into fillets. Salmon are split into sides. Anglerfish, carp, halibut, and sturgeon are cut into small pieces for smoking. Sablefish and salmon are cut into small pieces for kippering.

Salting

After butchering, fresh fish are washed, drained, and salted for varying lengths of time. Salting is an essential and important feature of smoking, as smoking is not a sufficient preservative in itself. Unsalted fish will usually sour or spoil under temperature and humidity conditions in the smokehouse before they can be cured. Then, too, the salted product is much more appetizing. Even if temperature and humidity conditions are favorable, a great deal more time is required for curing if the fish are not salted. Salt removes moisture much more rapidly than by drying in smoke. The length of time in salt depends on the species of fish, flavor desired, length of preservation required, and trade preference. Salting may be done either by immersion in brine or by scattering dry salt on the fish. It is not necessary that the fish be struck through as when they are to be entirely salt cured. A few hours are sufficient, depending on the climate and product desired. Some fishery products, such as smoked fillets, are salted only from 15 to 30 minutes. Fish such as halibut, herring, mackerel, or salmon may be smoked after being held in salt for a year. In these cases the excess salt is removed by soaking the fish in fresh water, though sea water is sometimes used. Fish given a heavy salt-cure and held in storage for some time before smoking are not so desirable in quality as those given a light salting and smoked immediately. In the Orient, fish are sometimes smoked without being salted. These fish are dried to a low moisture content and are not particularly appetizing to the occidental palate.

Drying

When the brining or salting is completed, the fish are washed or rinsed in fresh water to remove any excess salt. They are then hung on sticks, placed on trays, or arranged on movable racks which can be run into the smokehouse. Halibut or similar species may be dried for a day or two in the open air before being fastened to smoke sticks and hung in the smokehouse. It will be found that fish will have a more attractive appearance and require a shorter time in the smokehouse if dried in the open air for a few hours beforehand. In damp weather fish are sometimes dried by hanging in the smokehouse over a low clear fire with little smoke. It has been found that the use of electric fans or blowers is better than drying in the smokehouse in unfavorable drying weather.

The Smokehouse

There is no standard model for a smokehouse. Various types have been developed in different parts of the world. Many of the foreign types are in use in the United States. Some New York fish curers do not have a regular smokehouse. They smoke fish in warehouse rooms having brick walls, concrete floors, windows blocked, and the fuel burning in a metal trough on one side of the room; the smoke escapes through a skylight. Studies made to develop improved equipment for fishery products are limited. Lemon (1932) devised a smokehouse in which humidity and temperature could be controlled. Workers at the Atlantic Coast Experimental Station, Halifax, Nova Scotia, have developed a smokehouse which is expected to overcome many smoking problems and result in an improved product (Cooper 1937; Linton and Wood 1943). It is now being used commercially in the Maritime Provinces, Canada. After a study of the disadvantages of old type smokehouses and of the variables requiring control, a smokehouse based on aerodynamic principles was invented at the Torry Research Station, Aberdeen, Scotland (Cutting 1942; and Anon. 1946b).

The product to be smoked, the size of the market and shipping area, often determine the style and size of the smokehouse. In smoking some articles, such as finnan haddie, the smokehouse has special features which will be described under the discussion of the individual products. The smokehouse may be a small and simple structure when fish is smoked for local use, to obtain experimental data, or for introducing smoked fish to a new market.

A smokehouse for preparing small lots of fish is easily made by knocking the ends out of a hogshead or large barrel, setting it over a hole in the ground about 2 feet deep and a little narrower in width than the diameter of the barrel. Wooden strips are nailed inside the barrel on two sides, a few inches below the top. The ends of the smoke sticks rest on these strips. A loosely fitting wooden cover is placed on top, or it may be covered with damp sacking. Approximately 12 inches of the lower ends of a couple of staves may be removed to furnish a door to the fire pit, or a hole may be dug adjacent to the fire pit and fitted with a cover. The fire is fed through this hole, which also serves as a draft when the lid is partly raised. A smokehouse of this type is best for hot smoking but may be used for cold smoking if operated carefully. If the fire is permitted to flare up, however, the fish are soon scorched. For cold smoking it is best to dig the fire pit about 12 feet away from the smokehouse pit, with a covered trench between, which acts as a pipe. The fire pit should be placed on the side from which the prevailing winds come (fig. 27).

If a more permanent smokehouse is desired, and one that will handle a larger amount of fish or about 200 pounds at a time, a wooden shed is made 7 feet high and 4 feet square, inside measurements. Resinous wood should not be used in construction. About 12 inches above the ground a false bottom is placed with ¾-inch or 1-inch auger hole spaced at 2-inch intervals. On the two sides wooden battens are nailed spaced 12 inches apart, the first about 18 inches below the top. The ends of the smokesticks on which the fish are hung, or the wire-mesh bottom trays, if they are used, rest on these battens. The whole front of the house is hinged for a door. Three or four holes about 2 inches square are cut on the two sides a few inches below the roof, sometimes with slides to cover for use as drafts or ventilators. This shed is set over a pit about 2 feet deep, connected with the fire pit by a 10-foot covered trench. The pit below the smokehouse may be lined with brick. A terra cotta drain pipe, to act as a chimney, may be placed in the trench connecting the two pits (fig. 27).

The smokehouses used for curing herring in Maine and the adjoining Canadian Province of New Brunswick are barnlike wooden structures, with a louvre running the length of the ridgepole. The interior is divided by a series of vertical rows of two-by-fours. The spaces between the rows are called "bays." The scantlings in each row begin about 2 feet below the ridgepole and extend horizontally crosswise of the building, with the rows spaced from 12 to 18 inches apart.

They are placed within 6 to 8 feet from the ground. There is no floor as the fires are built on the ground. The average size herring smokehouse is about 30 feet long, 18 feet wide, and about 25 to 30 feet high.

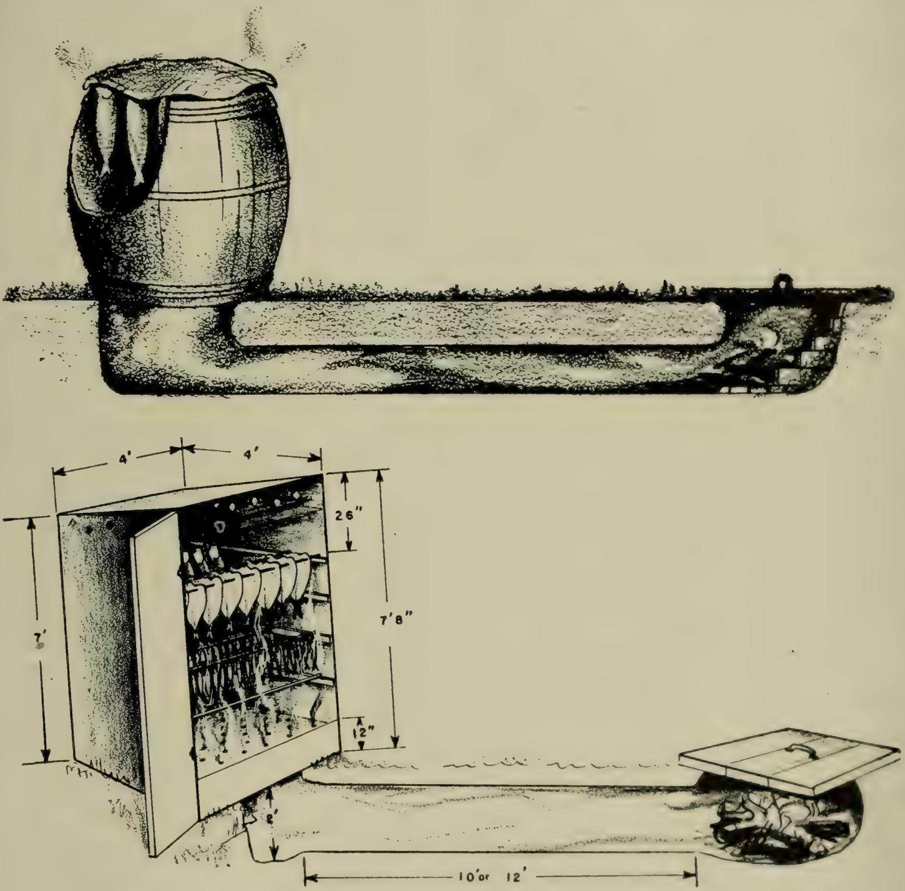

Figure 27.—Small smokehouses: Barrel smokehouse; shed smokehouse.

Some of the smokehouses used in New York, especially for hot smoking, are like the "ovens" used in Germany. They are made of iron sheeting about 9 feet high and from 4 to 6 feet square. The doors cover the whole front. Doors are usually of the two-leaf type and may be divided in two or more sections like a Dutch door. Drafts are usually built in the lowest section. Several ovens are built in a row and are sometimes held in a framework of brick. In some cases, the principal fuel is gas supplied by perforated pipes just above the floor on the two sides. Metal plates are fixed a few inches above the pipes. The plates are covered with sawdust which is charred by the gas flame below, when it is necessary to produce smoke. The gas flame is used for drying or cooking. In other instances gas is not used. Wood-chip and sawdust fires are built inside the house.

The smokehouses used in the Middle West for curing such fish as cisco, lake herring, tullibees, chub, whitefish, trout, and sturgeon are much like those described in the preceding paragraph, and usually consist of 3 or 4 smoking chambers built side by side. These chambers are constructed of brick with 8-inch walls and a ceiling of tinplate or galvanized sheet metal. Their dimensions range from 6 to 14 feet high, 3½ to 5 feet wide, and 6 to 12 feet long (inside measurements). Most of these smokehouses are intended to smoke only 3 rows of fish, the lowest hanging from 3½ to 6½ feet above the floor. The other rows are placed at intervals of 13 to 18 inches (all variations in spacing given depend on the species smoked) above the bottom row. The top row should hang not less than 18 inches below the ceiling. If the space between the ceiling and the top row of fish is insufficient, the hot air collecting at the top of the smokehouse will cook or blister this row of fish, often softening them so that they will fall. A number of small holes, an inch or two in diameter, are made in the ceiling to allow surplus smoke to escape to the chimney. The fire may be built in a pit below the level of the floor or the ovens may be gas fired, fed mechanically with sufficient sawdust to furnish smoke (Tariff Comm., U. S., 1927).

Portable smokehouses developed and sold by Middle West dealers in meat packers' supplies, for use in curing hams or bacon, are being used by some fish curers. The smokehouses are of the oven type. Some are gas fired while others are equipped with a wood grate. They have mechanical controls, to obtain any desired smoking condition regardless of weather. The price of one of these ovens varies from about $300 for the wood-burning type, with minimum controls, to about $500 for the gas-fired type, fully equipped with controls.

The smokehouse (fig. 28) is typical of the general style along the Pacific Coast in the United States and British Columbia, Canada. It is suitable for smoking a wide variety of fishery products on a commercial scale. This house is of brick and consists of a single chamber, with inside dimensions 12 feet long by 8 feet wide. The smokehouse is divided into two stories and a fire pit. The fire pit is 8 feet high and is separated from the first story of the smokehouse by an iron grating of ¼- by 1-inch bars. The fire pit door is made of sheet iron and is built in two horizontal sections, with a draft to regulate the fire built in the lower section. The walls of the smokehouse are 8 inches thick with a brick ledge every 12 inches. A two-foot passageway runs through the center of the smokehouse. Four 2½ by ½-inch flat bar hangers are fixed from the beams at the top of the smokehouse to the first floor grating, on each side of the passage. Angle irons (2½ by 2½ in.) are bolted to these hangers horizontally at intervals of 12 inches at the level of each brick ledge. The smoke sticks or trays are laid from angle iron to brick ledge, in loading the chamber for smoking. Ventilation is obtained through a galvanized iron vent house in the roof, furnished with movable louvres operated from the floor by chains. A recording chart thermometer, fixed to a side wall, provides means of keeping an accurate record of smokehouse temperatures, which is of value in obtaining data to determine processes.

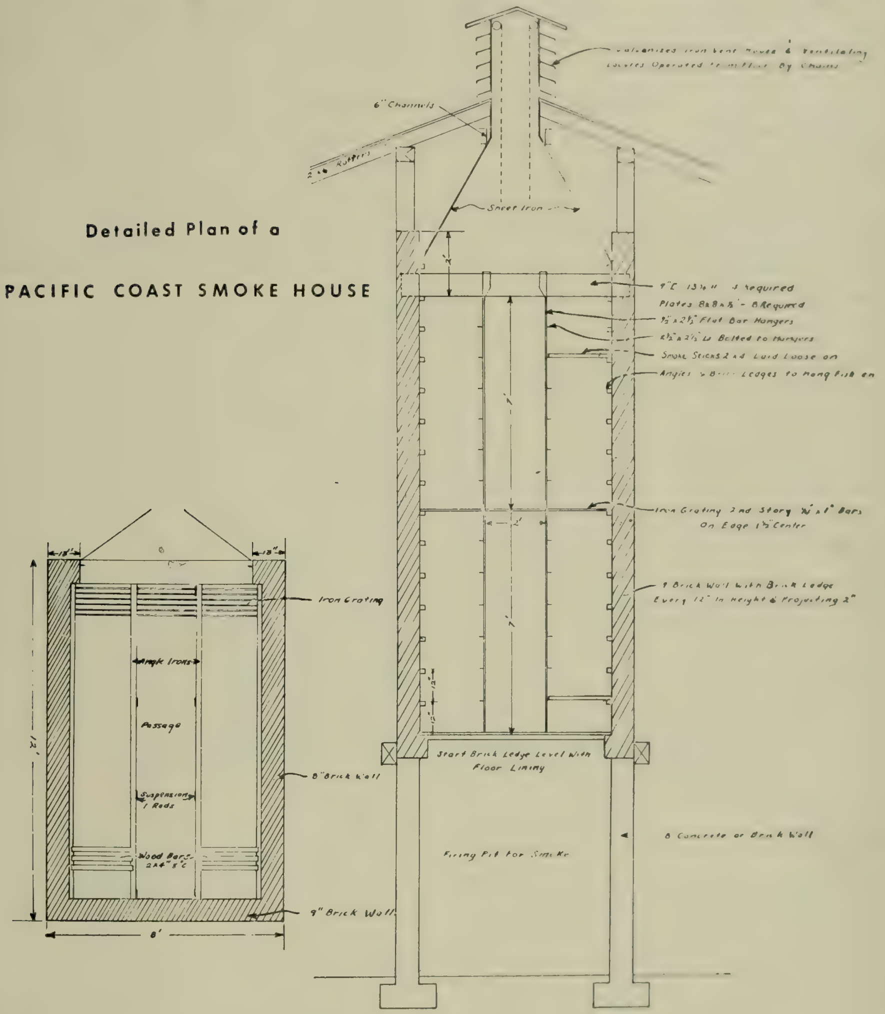
Detailed Plan of a
PACIFIC COAST SMOKE HOUSE
Galvanized Iron Vent House & Ventilating Louvres Operated from Floor By Chains
6" Channels
Rafters
Sheet Iron
9" [13¼ # 4 Required
Plates 8 x 8 x ½ - 8 Required
½" x 2½" Flat Bar Hangers
2½" x 2½" Ls Bolted to Hangers
Smoke Sticks 2 x 4 Laid Loose on
Angles & Brick Ledges to Hang Fish on
Iron Grating 2nd Story ¼" x 1" Bars
On Edge 1½" Center
9 Brick Wall with Brick Ledge
Every 12" In Height & Projecting 2"
Start Brick Ledge Level with Floor Lining
8 Concrete or Brick Wall
Firing Pit for Smoke
2'
12"
12'
18"
8'
Iron Grating
Angle Irons
Passage
Suspension Rods
Wood Bars 2 x 4" 8"c
8" Brick Wall
9" Brick Wall

Figure 28.—Plan of Pacific coast commercial smokehouse.

The smokehouses of large commercial curers are about the same size, but from 6 to 10 instead of a single chamber will be built in a row. In some cases, the houses are equipped with movable racks which can be loaded or unloaded outside. This arrangement is more convenient and requires less labor for operation, but the capacity is reduced.

The smokehouse designed by Lemon (1932) is of the cabinet type, of fireproof material and is portable. The laboratory model built at the Bureau of Fisheries (now Fish and Wildlife Service) technological laboratory is 7½ feet high by 3 feet square. The cabinet is divided into two sections, an upper enclosed compartment in which the fish are smoked and a lower compartment containing the operating mechanism. Smoke is produced by mechanically feeding sawdust on a metal belt drawn over an electric hot plate. The density of smoke is controlled by regulating the flow of sawdust. The smoke enters the upper section through a smoke pipe. A perforated false bottom or baffle and an agitator insure an even distribution of smoke. Two sets of thermostatically controlled electric heaters are attached to the upper side of the baffle and provide the necessary heat in the cabinet. A recording psychrometer makes possible the determination of the relative humidity, which can be controlled at any point between 8 percent and saturation by wetting filter cloths hung on the sides of the chamber.

The Atlantic Fisheries Experimental Station of Canada smokehouse is a tunnel-type structure, constructed mostly of wood, and is 14 feet long, 8 feet 7½ inches wide, and 5 feet 3¾ inches high. A schematic drawing showing the principle of operation is given in figure 29. It holds two movable racks with wire-mesh trays on which the brined fish are placed. The individual racks are 3½ by 4 by 3½ feet, with a capacity of 400 to 500 pounds of fillets. This smokehouse may also be used as a salt fish drier. A number of these houses have been installed by commercial fish curers in the Maritime Provinces of Canada, with good results.

Linton and Wood (1945) report as follows:

> Smoke is produced from sawdust and shavings in a simple type of cone smoker placed outside the house as shown in the sketch. An automatic type of smoker (Smokemaster) using sawdust is an alternative source of smoke. The supply fan draws air through the steam heater and smoke from the smoker into the house and exhausts an equal quantity of the waste air-smoke mixture. A propeller type fan, 42 inches in diameter recirculates the air and smoke over the fish within the house. With two cars of fish in the house the propeller fan blows the air-smoke mixture over one car of fish, through guide vanes and then over the second car of fish. The guide vanes at each end of the house are adjusted to direct the air and smoke evenly over the face of the cars of fish. The house was designed to offer little resistance to air flow and approximately one horsepower is required for the operation of the two fans. The air pressure inside the house is always slightly less than the atmospheric pressure and hence the smoke does not escape readily into the surrounding room. The temperature of the house is maintained constant by controlling the heat added to the incoming air in the steam heater. The maximum steam load is about 5 boiler horsepower.

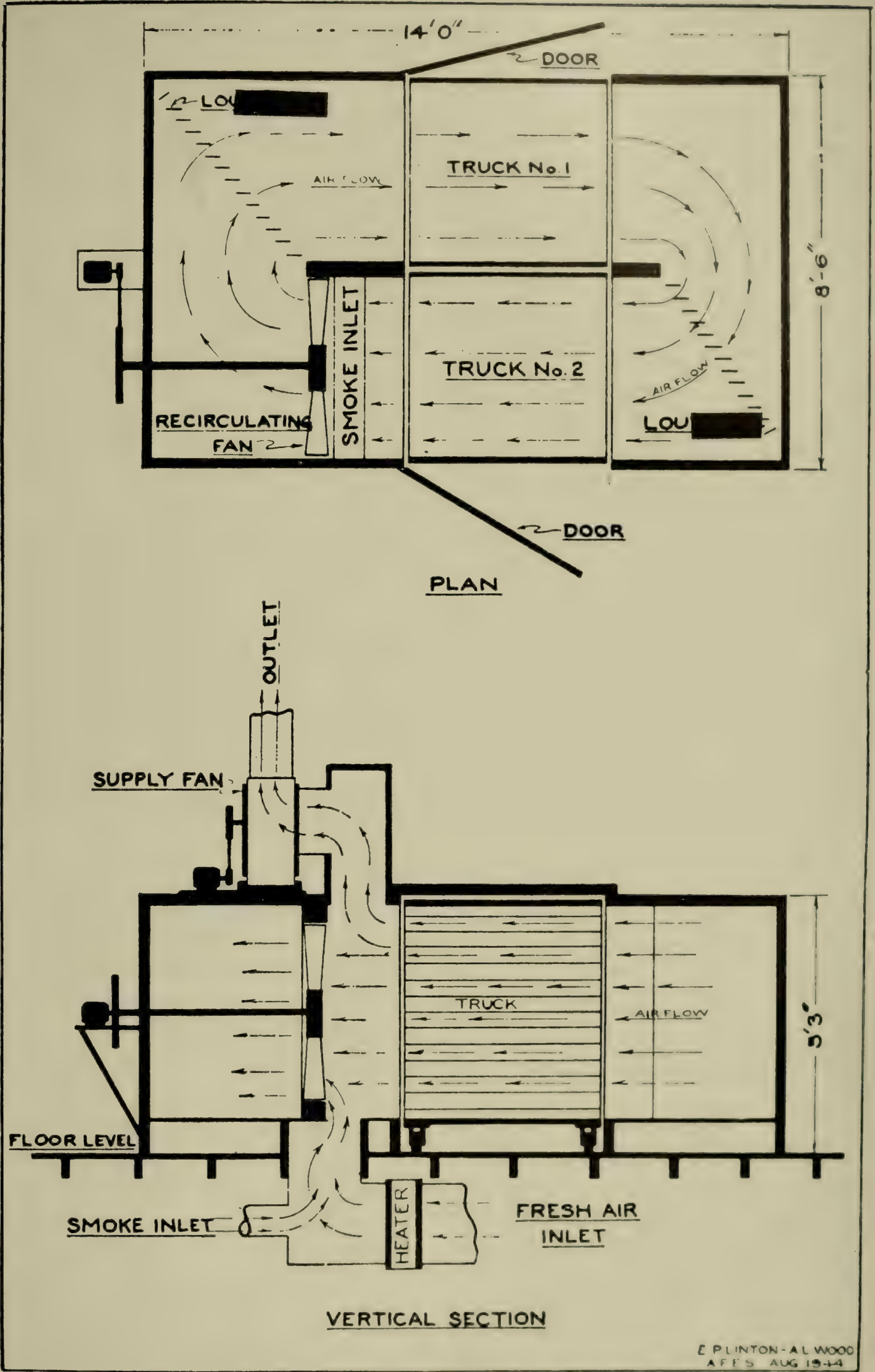

Figure 29.—Schematic drawing of smokehouse designed by the Halifax Fisheries Laboratory. (Courtesy, Fishery Research Board of Canada.)

Ice or mechanical refrigeration is used to cool incoming air in warm weather. This is necessary to prevent overheating in the house and also to dehumidify the air. In smoking and drying the fish by this method, the weight loss is largely controlled by adjusting the volume of fresh air admitted, while the depth of color depends on the amount of smoke forced into the house. Thus, weight-loss and color are made independent factors and any degree of dryness may be combined with any desired shade of color without the use of artificial colors. The time of smoking fillets has been reduced to an average of three hours.

Anderson and Pederson (1947) have developed a new type of smokehouse, more efficient in operation than the old kiln type. Fish are smoked under carefully controlled conditions in the Anderson smoke oven which has been adopted by about a dozen commercial fish curers in the Pacific northwest. This smokehouse is also of the tunnel type. Special emphasis is placed on simplicity of design and accurate control of the main variables in smoking: Smoke quality and volume, temperature, humidity, air velocity, and distribution. The smoke generator, usually a metal drum, is located outside the smokehouse, so constructed that the smoke is free from grit, soot, and ash. Smoke is delivered by a large diameter pipe, to permit condensation of tars and resins. The pipe line is also equipped with traps for catching and draining those materials. The smoke enters a mixing chamber where it is mixed with air. The air-smoke mixture is drawn through an opening across heaters by a blower. The smoke is then distributed through the smoking chamber by means of the volume blower and a baffle arrangement. After it has been deflected by the baffles, the smoke may either be exhausted through an outlet damper, or re-circulated through the blower and heater. Humidity is controlled by installing a cooling system just ahead of the air intake.

The construction of the smokehouse, method of operation, and new processes developed for operation under controlled conditions are described in Technological Report No. 1, The Smoke-Curing of Fish and the Application of a Controlled Method to the Process, State of Washington, Department of Fisheries. This publication should be consulted for further information on the process.

Fuels Used

Hardwoods are generally favored as fuel in smoking, both for drying and the production of smoke. The pitch or resins contained in softwoods, such as pine, are volatilized in burning and collect on the fish, giving it a strong characteristic flavor which ruins it for most markets. In New York, however, fish given a short hot smoke may be cured over a fire of excelsior and softwood sawdust. Different varieties of wood are used as fuel for smoking fish in the various regions of the United States. Alder is a favorite fuel on the north Pacific coast, oak or manzanita roots in California. White birch is preferred for smoking herring in Maine although old driftwood, a mixture of all sorts of wood brought in by the tide, may be used. Some of the woods that may be used for fuel for smoking fish in the southern States are scrub oak, live oak, hickory, river mangrove, and palmetto roots. Oak and hickory are favored throughout the Middle West. Corn cobs have been found to make a good fuel for smoking fish in this region but the fire must be watched carefully, as it has a tendency to flare up and get too hot. This applies also to coconut husks or leaf ribs in tropical or subtropical climates. Ash, beech, birch, juniper, and poplar are some of the other varieties of wood used in the United States.

Some woods are preferred as fuel because they give an aromatic or otherwise especially desirable flavor to the smoked fish. Sweet bay is used in southern States for this reason, and hickory through the Middle West and the South. The wood from old apple trees makes an excellent fuel when obtainable, giving an especially desirable color and flavor to the fish. Crab-apple wood is used in smoking oysters. The smoke from dead orange trees is reported to give a very attractive color.

In addition to suitability, the price and local varieties readily available are important factors in determining the types of fuel used for smoking fish in different parts of the world. In the British Isles, oak is believed to give the best color and flavor but as it is expensive and not always available, beechwood chips and sawdust are used. Peat and softwood sawdust are used in Scotland, especially for finnan haddie and smoked fillets. Beech and birch are used for smoking in Norway; however, in packing brisling (Norwegian sardines) oak is used exclusively for smoking the fish before canning. Green alderwood is used in Denmark, with oak or beech sawdust to smother the flames when a large volume of smoke is required. Oak wood, usually the small branches, chips, or sawdust, is favored in Holland. If oak is scarce, ash, birch, or poplar may be used. Mahogany sawdust from wood-working plants is a preferred fuel, if available.

Much also depends on the knowledge and care shown by the curer in the operation of the smokehouse. Stevenson (1899) warns that:

> The smokehouse should always be warm and dry before the fish are put in as the development of steam is apt to injure the fish. Even when using the same kind of wood, the length of time required to smoke an article of uniform grade depends largely on the condition of the weather, much longer time being required when the weather is sultry than when it is clear and windy.

Hanging Fish for Smoking

Various methods of hanging fish in the smokehouse are used, depending both on type of fish and on local custom. The fish may be hung on one or more S-shaped iron hooks, which are in turn hung over sticks running from one side of the smokehouse to the other. If whole, the fish may be hung on round, wooden sticks inserted under the gill flap and through the mouth. When these sticks have been hung with fish they are suspended from one side of the smokehouse to the other. If the fish are split, the smokesticks may be 2-inch square sticks. Nails are driven through the two sides of the sticks with the points projecting at a 45 degree angle. The intervals between nails depend on the average size of the fish smoked. The sides of fish are hung on adjacent nail points just below the bony neckplates, thus holding the fish open so that all of the flesh surface will be smoked. The fish are hung staggered on opposite sides of the sticks so that no two sides are exactly opposite each other. Another method is to run ½-inch iron rods through the fish just under the hard bony-plate at the neck, one rod on each side. Thus, each fish hangs from two rods (fig. 30). Twelve or more fish may be hung on a set of 2 rods 4 feet long.

Fillets may also be hung over three-sided sticks of wood which in turn rest upon the sticks at each side of the smokehouse. Chunks, cutlets or other small pieces, and shellfish such as shrimp or oysters, are placed on wire mesh-bottomed trays having a wooden frame. These are also used for fillets. Trays are easier to load and unload but the fish may show markings from the wire mesh. On the Pacific coast the bacon hanger is widely used. It was first used in cold-smoking salmon but now for other fish. The bacon hanger is described under Salmon Smoking (p. 214).

HERRING SMOKING

The Atlantic herring (*Clupea harengus*) was probably the first fish to be smoked on a commercial scale. Hard-smoked herring was one of the few food products in the Middle Ages which could be preserved for more than a short time with any degree of success. In an age when commerce was generally local, it found a market in many parts of Europe. As far back as the time of Edward I, Yarmouth was already noted for its smoked herring, and English merchants were exporting smoked herring to the Continent.

Herring is today the most important smoked fishery product in the world and is about the only one not regarded as a luxury article. The most important herring smoking centers are in England, Scotland, Holland, France, and Norway, in Europe; the provinces of Nova Scotia and New Brunswick in Canada, and the States of Maine and Massachusetts in the United States. More herring is smoked in Scotland than in any other country in the world.

The four important methods of smoking herring result in widely different products. Herring that have been heavily salted and given a long cold smoke until they are hard and dry are called "hard-smoked" or "red" herring. Red or hard-smoked herring has lost much of its popularity but is still cured in considerable quantity and is the source of boneless-smoked-herring. These are smoked fish which have been skinned and boned. Although hard-smoked herring has better keeping qualities, a lighter smoked product is now favored. Round herring which have been lightly salted and dried in a short cold smoke, are known as "bloaters." Bloaters have a short period of preservation. In the United States, only the large lightly smoked herring are classed as bloaters, but in Europe, fish of almost any size may be given this cure. Kippered herring are fish that have been split and

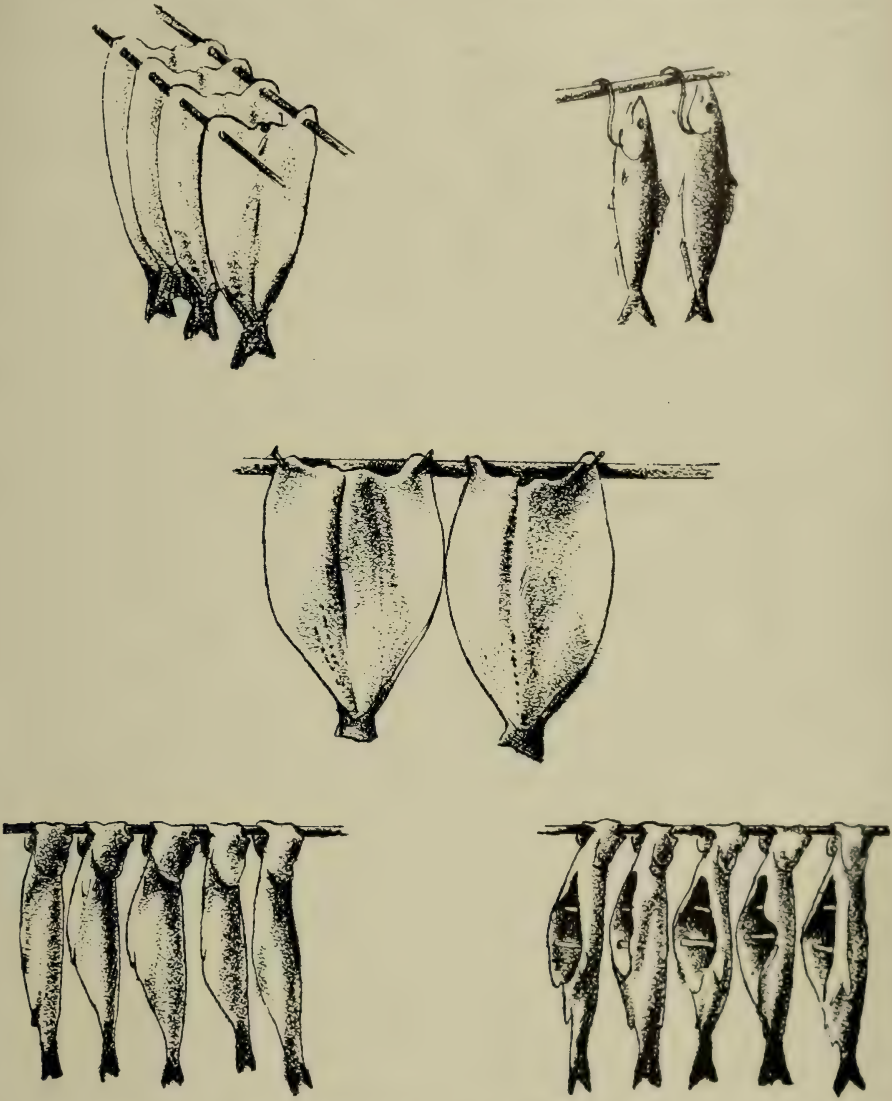

Figure 30.—Methods of hanging fish for smoking.

gutted, lightly flavored with salt and given a short cold smoke. "Buckling" or "pickling" are large, fat, round herring, lightly salted, given a short cold smoke, followed by a hot smoke which also cooks the fish.

Scottish immigrants of the late eighteenth century are said to have been responsible for the introduction of "red" herring to this continent. The curing of bloaters in America is reported to have begun in 1859 at Boston, Mass., where it was introduced from Scotland. The preparation of kippered herring is believed to have first occurred on this continent in Canada about 1890. According to some reports, "buckling" were first cured in America by early settlers from the Netherlands. Other sources state that this method was brought in by German immigrants about the middle of the nineteenth century.

Hard-Smoked Herring

The herring were formerly scaled before they were unloaded from the boat. This was done by having the fishermen shuffle through the pile of fish without lifting their feet, thus stirring the heap around. This step has been almost entirely discontinued since the close of the nineteenth century, as it was found to result in a large number of bruised and belly-broken fish. Also, the amount of handling necessary in smoking removes nearly all the scales without any special effort.

Either fresh or salt herring may be used in smoking hard or "red" herring. Fresh herring are preferred since a higher quality product is obtained. In Maine, the herring are obtained principally from weirs in the Passamaquoddy Bay region. Many of the weirs are owned by groups of farmers with water-front property. They cooperate in the construction and operation of the weir. The catch is divided among the owners, who may sell to the operators of large smokehouses near Eastport or Lubec, or may cure their shares individually, as they prefer. Some fresh herring are also imported from various points in New Brunswick.

The first step in curing hard-smoked herring is brining or pickling, if the fish are fresh. This may be done by mixing the herring with dry salt, the method favored in Europe. In America, the fish are given a light salting in brine. Fresh herring intended for smoking are then taken to the salting shed of the smokehouse as soon as they are landed and are placed in tanks with a capacity of about 4 hogsheads of herring. A hogshead will hold 1,200 pounds of fish. After the tank has been partly filled with 40° salinometer brine, enough herring are put into the tank to form a layer on the bottom. Approximately 30 pounds of salt is thrown on this layer of fish. Another layer of fish of about 2 barrels in amount, then goes into the tank, to be covered with a somewhat heavier layer of salt. This amounts to from 60 to 90 pounds. A third or top layer of fish is added and covered with a heavier layer of salt, amounting to from 180 to 300 pounds. The top layers are more heavily salted in order to prevent the herring from being unequally cured. This would occur if the salt was equally distributed, as the brine at the top would then become weak. The amount of salt used depends on the condition of the fish and the season of the year. If the herring are large or fat, or if the weather is warm, more salt is required. In cool weather and if the fish have just been caught, less salt than usual is needed. The time required to brine the herring is also dependent on the factors just mentioned. Small herring are salted from 24 to 36 hours. Large herring are salted up to 48 hours or even longer if they are very fat.

When the herring have been sufficiently salted they are removed from the brining tanks by dip nets, locally called "wash nets." The net full of fish is rinsed around in the brine of the tank to clean the herring and is then emptied on the stringing tables. The brine drains off while the fish are being hung.

If salt herring are to be smoked, the first step is to soak them in sea water to remove the excess salt. The herring are soaked or freshened from 12 to 15 hours. Some smokers change the water at least once while the fish are being freshened; others do not.

The smoke sticks on which the herring are hung are thin, wooden rods about ¾-inch in diameter, 3½ feet long, and pointed at one end. To string the herring, the back of the fish is held in the right hand. The left gill cover is raised by the right thumb and the pointed end of the stick is inserted through the gill cover and out at the mouth. The fish are shoved along the stick as they are hung, until it holds from 25 to 35 herring. A workman can string from 500 to 1,000 sticks in a day, (fig. 31).

When a stick is filled with herring it is rinsed in a tub of clean sea water and hung on a "herring horse." This is a rectangular frame resembling a rather crude stretcher with fixed legs. It is used to transport the sticks of herring to the smokehouse and as a rack for draining and drying. A horse will hold 45 sticks or about one barrel of herring. Each frame is carried out into the open air, weather permitting, and allowed to stand until the water has drained off and the fish are dry enough to hang in the smokehouse. The weather determines the length of the drying period, which varies from 1 to 5 hours. This preliminary drying hardens the gill covers so that the fish are not so apt to fall from the sticks during smoking. The fish also smoke more evenly and have a better appearance. If the weather is unfavorable, that is, foggy or rainy, the herring are hung in the smokehouse after draining for a few minutes. The smokehouse vents and doors are opened and the fish are dried over a clear fire.

Each smokehouse is divided by scantlings into a number of sections called "bays." These divisions are just far enough apart so that the ends of the smoke sticks will rest on the crosspieces or stringers fastened horizontally to the scantlings.

The herring are usually strung and dried in the morning and hung in the smokehouse in late afternoon. The smokehouse is not completely filled at one time. Herring suitable for smoking are often obtainable only in comparatively small quantities, and even if large amounts are available, the smokehouse is filled gradually, in order to make sure that the fish are well dried and that they will be more uniformly colored and smoked. If the smokehouse were completely filled with fish at one time, the air would become so saturated with moisture that the rate of drying and smoking would be delayed to such an extent that the fish might spoil.

At least two men are required to hang the herring in the smokehouse. One man stands in the bay with his feet on the beams, while the other stands on the ground and hands up the sticks of herring, two at a time, keeping the sharp end of the stick upward, so the herring will not slip off. The lower rows of the bays are usually filled first and the sticks are spaced far enough apart so that the herring do not touch each other. When the day's lot of herring has been hung in the smokehouse, the fires are lighted and the fish are given a preliminary smoke from 12 to 15 hours or until the herring are colored by the smoke. At the end of this time the fires are allowed to die down and the partly cured herring are transferred to a place nearer to the roof of the smokehouse. Another lot of fish is then hung in the lower part of the smokehouse and the preliminary smoking is repeated. The process is continued until the smokehouse

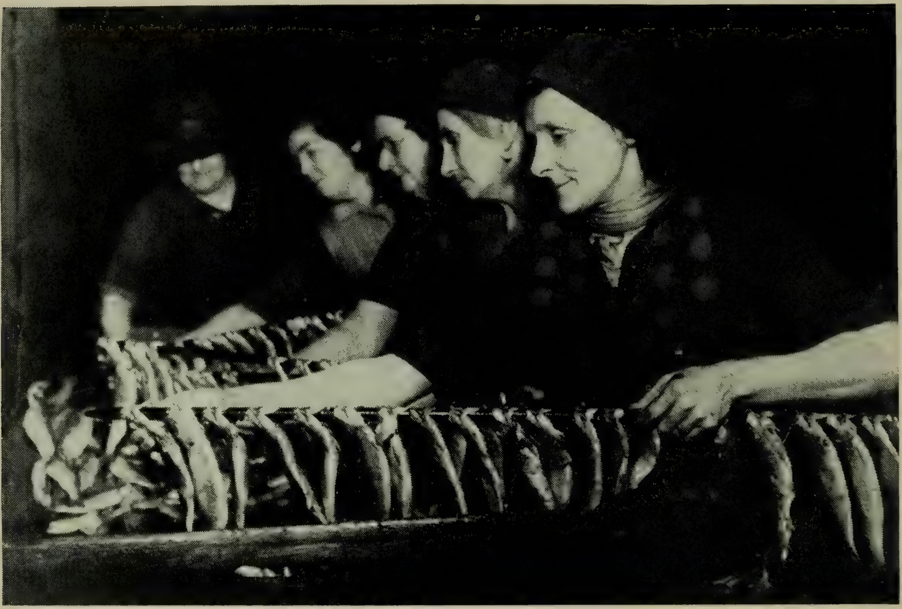

Figure 31.—Smoking bloaters showing stringing of herring on smokesticks. (Copyright photograph, courtesy *Picture Post*, London.)

is completely filled. For a large smokehouse this may require 2 weeks, while a small house may be filled in a few days. A smoldering fire is then kept up for 3 weeks until the fish are completely cured.

The fires for smoking the herring are built on the ground in the smokehouse and are usually spaced at equal intervals over the entire area, although in some of the smaller houses a low, continuous fire is built, following the lines of the back and two side walls. Almost any kind of wood except pine may be used as fuel, but white birch is generally preferred. Driftwood which has been soaked with salt water may also be used. The principal requirement is to have wood that will burn slowly and give off a good deal of smoke. The fires are kept burning continually night and day, and very slowly. The temperature should preferably be less than 70° F. If the smokehouse becomes too hot the fish may soften and spoil. The standard test to determine the degree of heat is to stretch out an arm between the rows of herring. If the air feels distinctly warm on the hand, the smokehouse is too hot. The more modern smokers have installed recording chart thermometers.

After being smoked, the herring are allowed to hang in the smokehouse until they are to be boned or otherwise prepared for shipping. If it is not possible to begin packing in a short time after the smoking process is finished, the smokehouse doors are kept open during the day, and if the weather is damp, low, clear fires are kept going in the smokehouse, to prevent the fish from absorbing moisture.

The herring are taken from the smokehouse to the packing shed where they are packed and graded as to size and quality. According to Tressler (1923), the most important grades of hard-smoked herring are medium-scaled, lengthwise, and No. 1. The best grade is medium-scaled, which is separated into two sizes, known as large and small-medium. Medium-scaled herring are packed crosswise in wooden boxes. A box of the large medium-scaled herring holds from 30 to 40 fish and the boxes of the medium-size average 45 to the box. The lengthwise herring are larger than the medium-scaled and were given the name from being packed lengthwise in boxes, which contain from 15 to 18 smoked fish. The No. 1 herring are the smallest and the lowest priced grade of those regularly packed; each box contains from 60 to 75 fish. Other grades of hard-smoked herring less generally recognized are tucktails and magdalens. According to a leading fish-curer, smoked herring are sold in boxes of 25 to 50 fish per box. The larger fish are called No. 1 and the smaller, No. 2. At one time some herring were packed 100 to the box, but this is rarely done today.

If boneless smoked herring are to be prepared, the smoked herring are dumped on wooden tables; the heads, bellies, and tails are clipped off with scissors. The trimmed fish are then taken to other tables where they are weighed. Women and girls then remove the skin and bones, using their fingers and a knife. The more expert workers can skin and bone from 100 to 150 pounds of herring daily. The skinned and boned herring are cut into small strips which are usually packed in light wooden boxes lined with paper and holding from 5 to 10 pounds. Some of the boneless smoked herring are packed in vacuum sealed glass tumblers holding from 5 to 8 ounces and in tin cans to about the same weight. The containers are not heat-sterilized. Preservation depends entirely on salting, drying and smoking. Boneless smoked herring is also packed in small cellophane or glassine envelopes holding 1 or 2 ounces.

"Red" Herring

Great Britain and the Netherlands were formerly large curers of red herring. Owing to changes in food habits and to better methods of food handling, the demand for the hard-smoked or red herring has decreased but it is still prepared in considerable quantity, especially for export. The method of curing red herring followed in England and Scotland (Duthie 1911), is briefly as follows: Fresh herring are roused (mixed) well with salt, then packed flat in barrels with plenty of salt, or about 30 pounds of salt to 100 pounds of fish. The herring are not gutted. The barrels are allowed to stand on end for 2 or 3 days after which they should be filled, headed, and laid on their sides. Brine should be poured into the barrels through the bunghole until the containers will hold no more. The herring are left to cure for at least 10 days, though some curers may leave the herring in salt for as much as 6 weeks. On the other hand, some curers start smoking after only 3 days in salt. Duthie states that curing may be done in the tanks used for salting bloaters. If this is done the herring should be well roused on the floor with salt and turned over during rousing with a wooden shovel. When herring and salt are thoroughly mixed, they are shoveled into the tank, with more salt thrown among the herring as they are filled in, and strong brine added after filling until the herring float. Curing in barrels is believed to be the more satisfactory method.

When the fish are considered to be sufficiently cured, they are strung on smokesticks as described in curing hard smoked herring. Each stick is about 56 inches long and holds an average of 25 fish. The sticks of herring are spread across long narrow tanks of water, about 4 feet wide so that the fish hang in the water. The herring are allowed to steep in these tanks for some 36 hours, the water being changed once or twice during the steeping period. The object is to soak out the surplus salt.

After the herring have been freshened sufficiently they are taken out to drain and dry. This is done on racks in the open air, if the weather is favorable. If damp or rainy, the herring are hung in the smokehouse at once, but are allowed to drain or drip from 12 to 24 hours before the fires are started. The same smokehouses used for kippered herring are generally used for smoking red herring today. When the herring have drained and dried sufficiently, a low fire of billet-wood (small chunks) is started and allowed to burn overnight or for about 12 hours. The fire is then allowed to die down and the fish cool for 24 hours. A low fire of billet-wood is again lighted and kept up for 24 hours. The fire is then allowed to die out for 24 hours. When it is relighted for the third time the fire is largely of chips and sawdust in order to obtain as much smoke as possible. The fish are smoked on alternate days over a period of from 3 to 6 weeks (depending on whether the herring are intended for domestic or export trade) before they are considered cured. The temperature of the smokehouse fluctuates between 57.2° F. (14° C.) and 66.2° F. (19° C.), averaging about 65° F. (18.3° C.).

Red herring are packed in small boxes and kegs or half barrels. The red herring barrel is a wooden-hooped, dry-ware cask like those used for grapes imported from Spain in prewar years. The heavily smoked fish (5 to 6 weeks of smoking) are known as "ham-cured reds" and "black herring." Fallen fish or headless herring are spiked on the nailed sticks used for kippered herring and smoked with the others. They go into the trade under the name of "red tenters" and "plucks."

Red herring are graded as follows:

Best selected reds, in kegs (80 to 100 fish).
Best selected reds, in boxes (40 fish).
Second quality reds in boxes.
Second quality reds in half barrels (189-200 fish).
Red tenters and plucks in half barrels.

Bloaters—American Method

Most of the bloaters cured in the United States are prepared from large, salt herring. Round or ungibbed herring are preferred, although gibbed fish are used when herring are scarce. The salted fish are soaked in large, square tanks of fresh water from 15 to 24 hours, the time depending on the saltiness of the herring. If the bloaters are made from fresh herring, the fish are held in a 90° to 95° salinometer brine for an average of 48 hours, then rinsed and hung on sticks. The salt herring, after soaking, are dipped onto a stringing table and strung on smokesticks as in the curing of hard or red herring but with fewer fish, generally 15, hung on a stick (fig. 31). In some places the herring are soaked for an hour or two, hung on smokesticks and then given a second soaking for 15 or 16 hours.

The herring are drained for a few minutes after soaking, then hung in the smokehouse, and the smoking process is begun, with ventilators and drafts of the smokehouse left open. Stevenson (1899) states that:

> In order to "bloat" the herring must be thoroughly moist, and after they have commenced to dry in the smokehouse the heat must be increased. If they are permitted to hang 10 to 12 hours without heating they will not bloat, but will become hard herring. The smoking is continued from 2½ to 6 days, when the fish are usually sufficiently cured.

On the Pacific coast the herring are smoked and dried over a low fire of alderwood at a temperature of 65° to 70° F. for 48 hours. At the end of that time a smudge is built by burning low heaps of sawdust to obtain as dense a smoke as possible with little heat. The temperature of the smokehouse should be about 60° F. This smudge is kept up for from 2 to 5 days, depending on the weather. In damp or unfavorable weather about 7 days are required to cure the fish from the time that they are placed in the smokehouse. Bloaters are packed in light, wooden boxes holding 25, 50 or 100 fish with a net weight ranging from 25 to 35 pounds, and in smaller boxes with a net weight of 10 pounds.

Bloaters—English Method

The method of cure followed in the British Isles differs to some extent from that used in the United States. According to Duthie "the bloater trade is more an English than a Scotch industry." The herring are brought in fresh from the drifters (gill netters). Trawl caught herring are not used if possible, as herring taken by otter trawl tend to be more or less bruised and damaged. The first step is to wash off the herring, then dry-salt them in Spanish salt, using enough salt to cover the fish and mixing both salt and herring well together. About 25 pounds of salt are used to 100 pounds of herring. Salting is considered a very important step, as herring too heavily salted will not have the flavor demanded by the trade. Duthie (1911) states that the herring are left in the salt "overnight," that is, from 12 to 14 hours. English curers have informed the author that if the herring are to be packed as bloaters they should not be salted more than 6 hours for a first-class product. Some smokers have large tanks in their plants to store herring in brine. Herring are salted in the tanks to be held until the herring season is over, when they are withdrawn as needed and freshened in water 12 to 16 hours before being hung on smokesticks.

The herring are rinsed free of salt and hung on wooden smokesticks as for hard or red herring. From 12 to 16 herring are hung on a stick. The fish should be well spaced, not touching each other. The sticks are hung in the smokehouse (fig. 32) and the herring allowed to drain and dry overnight, or up to 24 hours, the time depending on the rush of business. A fire is then built in a thin even layer over the entire floor of the fire pit. It is made of hardwood chips and sawdust, beech, birch, or other wood; one or two firms prefer oak. Duthie states that bloaters are smoked in much the same way as kippers and that a fire of hardwood billets is usually preferred to chips and sawdust. The soft fuel gives more color than is desirable, as bloaters should be dried rather than colored in the smoke. From 8 to 12 hours of smoking at a temperature of about 80° F. will generally cure the herring sufficiently for the British market. The product is allowed to cool and it is then packed

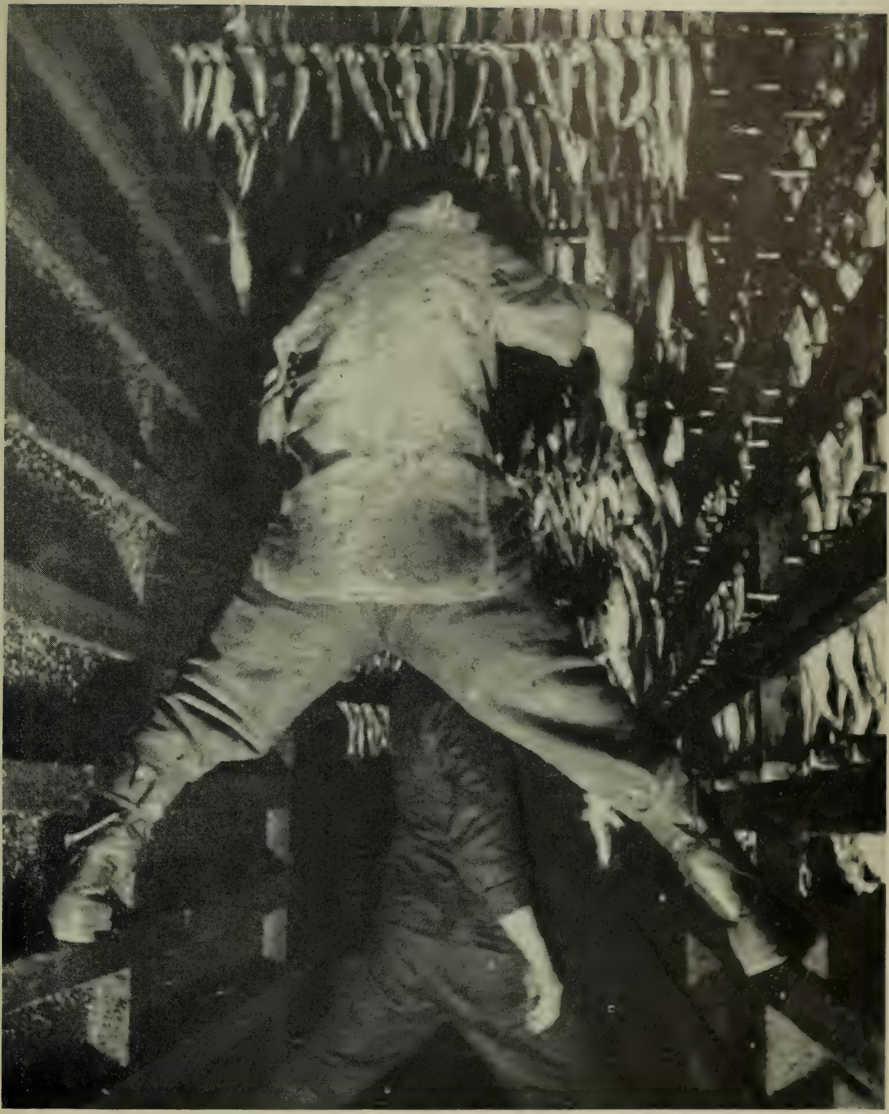

Figure 32.—Smoking bloaters showing hanging of herring in smokehouse. (Copyright photograph courtesy *Picture Post*, London.)

in boxes, usually of one stone (14 lb.) each.

Kippered Herring

Kippered herring is the most important cured fishery product in Great Britain. It is not so popular in the United States. This may be ascribed, in part at least, to the fact that in the past herring of small size and poor quality have been kippered in an effort to dispose of otherwise unmarketable fish. The demand for kippered herring is slowly increasing in the

United States; and a well prepared product, properly merchandised, should eventually find a considerable market.

The best kippered herring is supposed to come from Scotland and the Isle of Man, but considerable quantities of kippers are cured in many of the fishing ports throughout Great Britain. A well-prepared kippered herring makes a tasty breakfast dish. Almost every firm differs as to one or two details of the curing process for kippered herring, but in general the process is as follows: Fresh herring only are used for kippering. The fish should be of fair size and in good condition. A reasonably good fat-content is desirable.

After being washed to remove slime, blood, scales, and other debris, the herring are split down the left side of the backbone from the tip of the head almost to the tail and are then opened to lie flat in one piece. Gills, viscera, blood and membranes are cleared away, and the fish are washed well in fresh water. After draining for a few minutes, the herring are immersed in a 90° to 95° salinometer brine. The time required for brining averages 20 to 30 minutes. The principal factors deciding the length of the brining period are the amount of fish in a batch, the condition of the fish, as soft herring require more brining than firm fish, and the market where the product will be sold. Some markets like a saltier product than others. The length of preservation desired must also be considered.

The herring may be dyed at this point or the dye may have been previously added to the solution in which the fish were brined. If added to the brine, the amount of dye is regulated by the length of the brining period. If not, the herring are dipped for about 30 seconds in a dye solution with a strength of about 1 to 2,000, that is, 1 gram of dye to 2 liters of water. The dye used is either annatto or a similar compound. Curers state that good dyeing can only be learned by practice and like brining, varies, according to the weather, condition of fish, and the amount handled in a batch. Fish curers are almost unanimous in the belief that the better quality kippers should not be dyed, but occasionally some are dyed to meet the demands of a special trade. This practice is much more general with kippered herring of lower grade.

After draining a few minutes, the herring are hung on smoke sticks. The sticks are wooden bars 4 feet long by 1½ inch by 1 inch. There are 16 nails driven in on each side, the points projecting upward at a slight angle. The nails are in pairs 3¼ or 3½ inches apart, according to the probable size of the herring, and about 1½ inches between each pair of nails, so that a stick will hold 8 herring on a side. The fish are hung by piercing the head through a pair of these nail points so the herring are open flat with no two fish touching. The sticks of herring are hung in the smokehouse to drain and dry until evening. The lowest row is hung about 12 feet above the firepit floor. Some curers use almost any hardwood chips or sawdust while others use only oak, claiming that other woods do not give the smoke flavor essential to good quality kippered herring (Duthie 1911). The fish are smoked lightly for 6 to 8 hours. One or two refuelings of the fires are usually needed, the second and third fires being lower than the first with less heat and more smoke. Some heat is necessary at first if the herring are to take color properly but the fish must not be overheated or they will be scalded and fall from the hangers (fig. 33).

The kippered herring are allowed to cool and dry for several hours. If this is not done the herring are apt to sweat and arrive in bad condition. After cooling, the herring are sorted and packed in boxes of several sizes, the most popular holding a stone (14 lb.) of fish. A growing export trade is being done with the United States and the British Commonwealth. Kippered herring intended for the export trade or the best class of local trade, are wrapped in pairs in cellophane envelopes before packing in boxes.

A development in the curing of kippered herring that has resulted in an improved product was introduced by a firm of fish curers in Fleetwood, England, some years before the outbreak of World War II. This is the boneless kipper. The herring are dressed mechanically (fig. 34). They are headed, the thin part of the belly is cut off, and the blood, viscera, and backbone are removed by a machine handling around 2,000 fish per hour. There is no difference in the brining and smoking procedure. The boned kipper must be handled more carefully than fish dressed in the ordinary manner but the product is of high quality and is practically free from bones and waste. In a number of other packing centers, boneless kippered herring are being prepared by hand. The author has put up several experimental hand-dressed packs and finds little difficulty in using this method. Loss in dressing is slightly greater but the improvement in product more than balances any loss in weight. The boneless herring may be dressed almost as quickly as by the present method for the non-boned product.

The method for kippering herring in the United States differs but slightly from the British cure. At least one of the important curers follows the British cure exactly. The principal differences are that the fish are given a heavier brining and a longer smoke cure, that is, from 12 to 16 hours. Since this country is larger and the demand here is rather uncertain, a more durable product is required. Even then kippered herring will not keep long at ordinary temperatures. The product is packed in 10-pound wooden boxes and is usually stored at temperatures of 33° to 35° F. Experimental freezing of kippered herring has not been particularly successful. Studies at the University of Washington College of Fisheries indicated that the best results were obtained by freezing fresh fish, to be thawed and kippered as re-

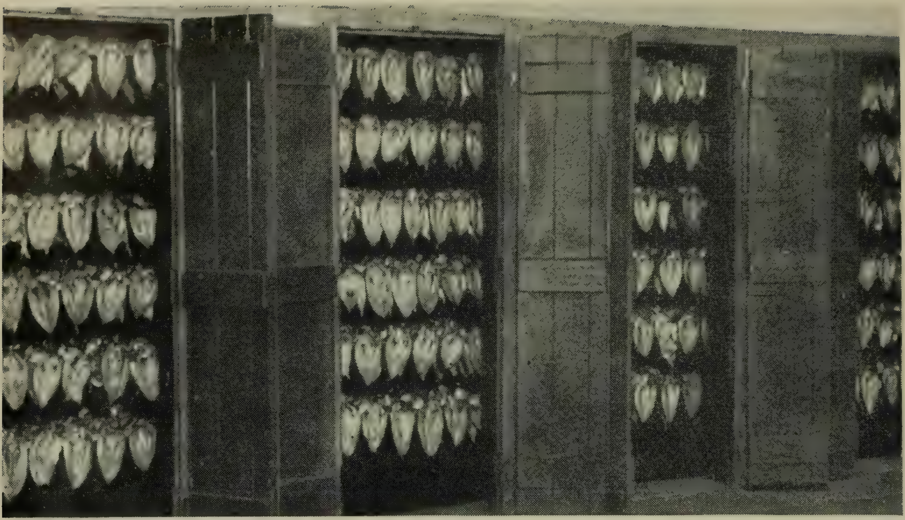

Figure 33.—Kippered herring in smokehouse. (Copyright photograph courtesy British Ministry of Food.)

Figure 34.—Machine splitting, eviscerating, gilling, and cleaning herring in preparation for kippering. (Copyright photograph courtesy British Ministry of Food.)

quired. The smokehouse developed at Halifax laboratory of the Fisheries Research Board of Canada has been found suitable for smoking kippered herring commercially in Canada. It may also be used with mackerel and most other smoked fish, according to information from Canada.

Buckling

A small amount of herring is smoked as buckling in the United States, principally in New York. Buckling is an appetizing smoked fish product and deserves a much wider market. It is believed to be of Netherlands origin but is one of the principal smoked fishery products of Germany. Fresh, fat herring of medium size are preferred in the preparation of buckling. The fish are rinsed in fresh water to remove blood, slime, scales, and any other debris. After draining, the herring are left in a 70° to 80° salinometer brine from 2 to 3 hours, the length of time depending on the strength of the brine and size of the herring. In some districts the fish are not cured in brine but mixed with dry salt and left in a heap for about 2 hours or until sufficient salt has penetrated the herring.

The herring are rinsed in fresh water, then strung on iron or wooden smokesticks or spits. The method followed in stringing is that used in stringing hard-smoked herring or bloaters. Each stick is about a meter (3.3 ft.) in length and holds from 15 to 25 herring, the number varying according to the size. Care must be taken to space the fish so that no two touch. The sticks or spits are laid on wooden frames holding from 15 to 25 spits. These frames are slid into movable or stationary racks, where the fish are left to drain. In some cases when the weather is favorable the herring are also given a sun-drying in addition. This increases the capacity of the smokehouse as a greater quantity of fish can then be cured during the working day.

When the fish are properly drained, the frames are placed in the smokehouse. A fire is built to burn with a bright clear flame, without much smoke. Sticks of alder, beech, or oak are the fuel used. After 1 to 1½ hours, the herring are considered dry. The fire is covered with alder chips to produce a heavy smoke and give the fish the golden yellow color required. If the chips do not give off sufficient smoke they may be dampened occasionally by a sprinkle of water; this is also done if the fire burns up too strongly. The regulating damper at the top of the chamber is first closed half-way, and later all the way. It takes approximately 1 to 1½ hours to complete the cure. The whole process requires about 3 hours. The quality of the product is said to depend largely on the size and quality of the herring and the care with which the fires are regulated. The buckling are marketed in boxes of 5 to 14 pounds. Herring split down the back like kippered herring and then given the buckling cure are known as "fleckheringe."

Modified Buckling Cure

The writer has found that the following process, a modification of the buckling cure, will produce an appetizing article suitable for distribution in the United States. Fresh or frozen herring may be used. Frozen herring should be thawed out overnight. The herring are covered with three-quarter ground salt, using about one part of salt to four of fish. They are allowed to cure from 2 to 3 hours, and are then rinsed off in fresh water. After draining, the fish are given a drying of from 2 to 2½ hours in an artificial drier at a temperature of 60° F. preferably, and not more than 70° F. All surface moisture should be removed by this time. After being strung on rods, the herring are given a cool smoke at a temperature no higher than 70° F., for 6 hours. The fire is then built up with the result that the fish are partly cooked for 45 to 60 minutes, at a temperature of 180° F.

Chill - storage temperatures between 33° and 36° F. must be used if the product is to be kept in good condition for periods longer than a few days. It must be handled even more carefully than kippered herring.

Sprats

Smoked sprats (*Clupea sprattus*) are a favorite product in all the countries of the Baltic area, especially in Germany. Some smoked sprats or "Keiler Sprotten" were imported into the United States from Germany before World War II. A smoked sprat substitute is now cured in the United States, prepared from the Atlantic herring (*Clupea harengus*). The German process is briefly as follows:

Fresh sprats are graded for size so that each lot is uniform. They are then brined for 1 hour in a salt brine testing 80° salinometer. After being rinsed thoroughly, the sprats are piled in baskets to drain off the surplus moisture. They are then hung on iron spits, much as in sardine canning; that is, a thin iron rod is run through the eye sockets of the fish. When a rod is filled it is placed in a wooden or iron frame. However, the fish must not be hung too closely on the rods. The frames are stacked to a depth of 4 or 5 frames in the standard type hot-smoking oven used for buckling. The smoking process is almost the same as for buckling; that is, the fish are first cured over a bright, clear fire for about 1 hour. The fire is then covered with alder chips and the damper closed, building up heat and a dense smoke. The cure is completed in about an hour, so that the entire smoking process takes 2 hours or a little more.

The smoking of sprats in the United States is confined to New York City, which is the only commercial market for this product. Some sprats have been smoked in Nova Scotia and sent to New York. The American sprats are cured from small spring herring, 5 to 7 inches in length. Some frozen herring shipped in from Newfoundland are used. The herring are first washed thoroughly, allowed to drain for a few minutes, and then brined for 45 minutes in a 90° salinometer brine. After being rinsed, the fish are drained thoroughly, then spread thinly on wooden-frame trays with bottoms of wire mesh. The herring should not be allowed to touch each other. The trays are placed in a finnan haddie smokehouse at a distance of 18 inches to 2 feet above the fire, where the fish are smoked from 2 to 4 hours. At the end of this time they should have a golden brown color and be sufficiently cooked so that they are ready to eat. These sprats remain in good condition for a few days only.

SALMON SMOKING

Smoked salmon is prepared by several different methods from raw material of various grades and types. Formerly a large proportion of the pickled or hard-salted red salmon from Alaska was shipped to the eastern part of the United States and Europe for smoking. Today, mild-cured chinook or king salmon are most used in smoking, but varying quantities of silver or coho salmon are also mild-cured. These sell at a somewhat lower price than mild-cured king salmon, and make excellent smoked salmon. Some fresh Atlantic salmon is smoked after being salted very lightly for a few hours. This product is generally known as "Nova Scotia" salmon in the eastern markets and is regarded as the finest grade of smoked salmon, but far less is used than of mild-cured salmon for the same purpose. The only smoked-salmon product requiring an appreciable quantity of fresh raw material is kippered salmon, for which fresh or frozen salmon is invariably used.

American Method

In preparing smoked salmon from mild-cured fish, the sides of salmon are taken out of the tierce and soaked overnight in fresh water, or for a period of 12 to 16 hours. The water is changed two or three times. Ten or 12 hours of freshening should be sufficient but a more thorough soaking may be required to satisfy some markets. Certain smokers freshen salmon for 10 hours in a tank with running water, especially if a large quantity is to be smoked. When sufficiently freshened the salmon are washed to remove all traces of blood, slime, or encrusted salt, then carefully wiped with a clean soft cloth.

The next step is draining and trimming. Draining is often done by water-horsing; that is, the salmon are placed in a pile, flesh side down, and a weight is placed on top to press out the water. After enough moisture has been drained from the flesh the sides are trimmed of any ragged edges and are taken on barrows or hand trucks to the smokehouse.

Wire hangers are used for hanging the salmon on sticks in the smokehouse. These hangers are made of steel wire or light iron and have six points at the lower end at right angles to the frame and a curving hook at the top, to hang over the smoke stick. A side of salmon is laid out flat, skin side up. The points of a hanger are pressed through the skin at the nape or neck end. The side is then passed to another workman in the smokehouse, who hooks the handle over a round smoke stick. In hanging the salmon, care is taken to leave sufficient space between sides to guard against crowding the fish together or overloading the smokehouse. If this is not done, the salmon is unevenly smoked and of inferior quality.

The time required for the smoke cure depends primarily on how long the salmon are to be kept, and on market preference. On the Atlantic coast, light smoking for 8 to 10 hours is considered sufficient. In fact, some curers dry the fish to the desired texture in an oven, using very little smoke. In other sections of the country a longer cure is required because the smoked salmon may not be consumed within the next few days and the trade desires a product with a definite smoke flavor and somewhat firmer texture.

It is the opinion of some fishery authorities that the Pacific and midwestern smoked salmon are superior to the average Atlantic product. The Pacific coast method requires a longer cure, more work, and entails more expense than the Atlantic method. The following method is descriptive of western salmon-smoking practices (Jarvis 1936b) : After the smokehouse has been filled, a clear fire is started in the pit below and for some hours the fish are smoked over a clear fire with the ventilators left open so that moisture can escape. This prevents the salmon from sweating in this initial period of smoking, which is really more or less a drying process. A few smokers dry off the salmon using mechanical fans until a thin shiny skin has formed on the surface, before hanging in the smokehouse.

When the first period of the smoke cure has been finished, that is, after 24 to 48 hours of light smoke, with smokehouse ventilators open, the ventilators in the top of the smokehouse are closed and the fire is smothered with sawdust. A dense smoke is thus created in which the salmon are cured for an additional period that requires 48 to 72 hours. For a still more durable product, one that may be marketed, over a wide area and will keep longest under average conditions of temperature, handling and storage, the smoke cure may require a week. In this case, the fire is kept low and smoldering during the entire period of the cure. A dense smoke is not formed but the product acquires a distinct smoke flavor because of the long cure (fig. 35). It is as much a process of dehydration as smoking.

When the cure is completed the smokehouse doors and ventilators are left open. After the smoked sides are sufficiently cooled, they are weighed, wrapped in oiled or parchment paper, and packed in light wooden or fiber boxes with an average net weight of 30 pounds. Smoked salmon must be kept in chill storage at temperatures of 34° to 40° F. if they are to be held any length of time, especially in summer. A well smoked side of salmon should have a smooth, glossy surface with a light brown color. The flesh inside should have the texture of smoked ham.

The length of the smoking period and other factors involved in smoking salmon vary according to locality, type of product demanded by the trade, temperature used in the smoking process, atmospheric temperature, humidity, and similar factors. The process must be altered to meet changes in these conditions. Exact data as to temperatures, length of time, density of smoke, and other factors required to give the best results are lacking. This is a cold-smoking process, however, and though the fire must be sufficient to dry the salmon it must not give off too much heat or the fish will be partly cooked, so that it will not have the desired texture and flavor and will soon spoil. The temperature should not exceed 90° F. and in general should be lower, or about 75° F. if atmospheric humidity is at all high. As to the best type of fuel, alder wood is favored and is most commonly used on the Pacific coast but almost any nonresinous wood, such as maple or beech, gives satisfactory results. Oak and hickory are favorite fuels among salmon smokers on the Atlantic coast but they are often unobtainable and many substitutes are used as fuel for smoking.

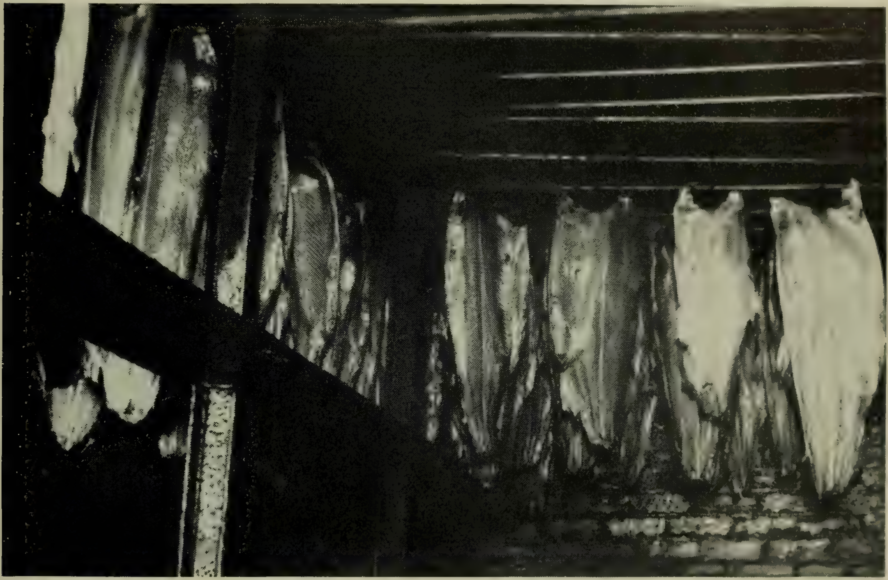

Figure 35.—Smoking salmon, Pacific coast cure.

A small amount of smoked salmon is sliced like bacon or ham, wrapped in cellophane and sold in half- or quarter-pound packages to the delicatessen and grocery trade. Sliced smoked salmon is also packed in 4- or 8-ounce screw-top glass jars. Small packages holding 1 or 2 ounces for individual servings are mounted on cards for sale to the tavern trade. Hard smoked or heavily cured sliced smoked salmon is also packed in quarter-oil cans of the type used for Maine sardines. A little olive or cottonseed oil is added to each can which is then sealed hermetically but not sterlized. While this product is not as perishable as the usual smoked salmon, it does not have an unlimited period of preservation and should not be exposed to high temperature or other unfavorable storage conditions. The maximum preservation is achieved by keeping this product in a refrigerator or refrigerated showcase. Some smoked salmon in oil was imported from Japan and various north European countries before World War II. This product was also unsterilized but in certain cases preservatives such as urotropin were added. The use of this preservative and a number of others are made illegal under the U. S. Food, Drug and Cosmetic Act. Sodium benzoate may be used in amounts less than one-tenth of one percent if presence and amount are stated on the label.

Scotch Method

Scotch smoked salmon is generally known as kippered salmon but the method is different from that used for kippering salmon in America. The product also is different and most closely resembles the light-smoked salmon of the United States. There is some difference in the method of cure, two variations being given here.

The salmon are washed thoroughly, the heads are removed and the fish are split down the back. The belly cavity is cleaned of viscera and other offal, coagulated blood is scraped away, and the fish again washed thoroughly to clean them of blood stains or slime. After draining until surplus moisture is removed, the fish are rubbed with a mixture of salt and brown sugar. They are packed in a tub or barrel, with more of the mixture between the layers of fish. The flesh should absorb enough of the salt-sugar mixture for smoking purposes in 48 hours. The fish are then rinsed and three small double-pointed sticks, with a length approximately equal to the width of the fish, are fixed through the skin, one near the napes, one about midway and the third near the tail end. The sticks are intended to keep the fish spread out during smoking. The salmon are then air-dried for a few hours, after which they are hung in a kippered herring or finnan haddie smokehouse and smoked for 10 to 14 hours. This is a very mild cure and the salmon remain in good condition for only a few days at ordinary temperatures (Duthie 1911).

In the second method, the fish are first washed thoroughly, then the skin is scored lightly with a knife at intervals of about 2 inches to penetrate the skin but not to cut into the flesh. The scoring is done longitudinally. The salmon are then split in sides and cleaned of all viscera or other offal. Any blood remaining in the veins around the belly cavity is gently pressed out from the flesh. The sides are then washed thoroughly in ice-cold water, where they are allowed to remain for about half an hour to make the flesh somewhat firmer. The sides are drained to remove surplus moisture and trimmed of any ragged bits of flesh or pieces of membrane.

A mixture is made in the proportion of 6 pounds salt, 4 pounds brown sugar, 1 ounce saltpeter, and ½ ounce each of bay leaves, black peppers, cloves, coriander seed, and allspice. The spices are ground or crushed and mixed well with the other ingredients. The sides of salmon are dredged in this mixture which is also rubbed into the flesh. The sides are picked up with as much of the curing mixture as will cling to the flesh and packed in a tub, scattering a small amount of the mixture between layers. After 48 hours the sides are taken out of the tub, scrubbed and soaked in cold fresh water for 1 hour. The sides are then laid in a small pile, flesh side down, with weights on top to press out moisture. They are left here several hours.

The sides are then hung on smoke sticks and dried in the open air until a thin skin or pellicle forms on the surface. A fan or blower could probably be used for this purpose. When the salmon are sufficiently dried they are hung in the smokehouse where they are smoked over a low fire of beech or other white wood-chips for 16 to 24 hours. A dense smoke is then built up and the fish are smoked in this for an additional 8 hours. At no time should the temperature in the smokehouse be more than 80° F. This smoked salmon has a greater length of preservation than the first but cannot be expected to remain in good condition more than 10 days or 2 weeks at room temperature.

Norwegian Method

The following description of the Norwegian method of smoking salmon was given by Duthie (1911): "Cut the head off, and split the fish down the back. Wash it clean, and then put it in salt or ordinary pickle. After lying in the pickle for 3 days, the fish is taken out and washed in clean, fresh water and then stretched upon pieces of lath. These pieces of lath are about 1½ inches broad, but quite thin. They are cut to a length corresponding to the breadth of the fish, and sharpened at the end. One of these spits is put across the back of the fish at the lugs or shoulders, another about half-way down, and if the fish is large, another further down, the points of the spits being stuck through the skin of the fish. The fish is then 'tentered' and hung in a chimney, where it is smoked over a fire of fir branches for 1½ to 2 days. Salmon cured by this process are somewhat similar in appearance to an Aberdeen-cured haddock, but rather darker in the color. They are cut into collops and sold for immediate use, generally at high prices.

"Salmon meant to be kept for 2 or 3 months are much harder cured. The fish are split into halves to facilitate the operation of curing, and to make them easier to handle and pack. The barrels for packing should be clean and tight, and preferably of hard wood. It is advisable first to rub the fish well with a mixture of brown sugar and fishery salt, as in the Scotch method, and a little of the same mixture might be thrown in between the pieces of fish as they are packed into the cask. Hard packing should be avoided; sufficient room should be left to let the pickle circulate freely. The barrel should be filled full of strong, clean pickle (which in this case had better be filtered) the end put in, and the barrel laid on its bilge. To properly cure, salmon treated in this way should have the pickle poured off and fresh pickle substituted, the fish being well washed in clean pickle before being repacked. As a precautionary measure, the fish might be taken out, washed, and repacked after 2 or 3 weeks in cure, even if there were no suspicion of staleness. When required, the pieces of fish should be taken out, well washed in clean, fresh water, and smoked in the same way as the milder-cured fish. Owing to the rich nature of the fish, this is the only method by which it seems possible to preserve salmon for any length of time apart from canning. Dry-curing would fail to preserve such a fat fish. In Norway, all the smoking is done in the chimneys of dwelling-houses in much the same way as finnan haddie curing was originally done on the Kincardineshire coast."

Experiments in the Norwegian method as given above indicate that a few revisions would improve the product, at least for this market. Smoking with a fire of fir branches was found to give a decidedly bitter taste. The flavor of the fish was much better when a low fire of green alder or some hardwood was used. The fish smoked much better and with a more even color when they were dried in a current of air until a pellicle or film is formed on the surface, before putting them in the smokehouse.

German Method

Fresh Rhine River salmon was the chief source of raw material for salmon smoking in the nineteenth century. A small amount of Rhine salmon is still smoked but most of the salmon used for smoking during the past 40 years has been mild-cured salmon imported from the United States. Small additional amounts of fresh or frozen salmon have been imported from Norway.

The first step in smoking mild-cured salmon is to freshen them in running water. Mild-cured salmon are freshened from 5 to 10 hours. In winter, freshening takes longer, about 15 hours for mild-cured or 30 hours for heavily salted salmon. Frozen salmon are thawed in cold water, cleaned thoroughly but not scaled, then are split into sides or split open to lie flat in one piece and placed in enough salt to cover. They are left in salt from 2 to 3 days, then rinsed and set out to dry in the air. Mild cured salmon are also set out to dry when they are sufficiently freshened.

The salmon are inspected either just before or after drying, and any sides showing cracks or breaks in the flesh are given a protective coating to prevent additional breaks and to keep the flesh together in a single solid piece. This also permits the sides to have a more attractive appearance after smoking and they may be readily cut in thin slices. A solution of isinglass is often used for this purpose. Another coating is composed of a mixture of gelatin, glycerine, powdered pumice, and chemically purified fish glue (Hoffman; undated).

After drying for several hours, or when no surface moisture is apparent, the sides are taken to the smokehouse. Several different types of salmon smokehouses are used but nearly all are of the oven type used in the curing of bacon. A typical smokehouse is 4 meters (13.1 ft.) high. The salmon are hung at a minimum distance of 2 meters (6.6 ft.) from the fire. During the first part of the smoking process the fish are cured over a smoldering fire of small logs, which is later covered with sawdust and chips to build up a denser smoke. It is believed that oak, alderwood, or mahogany sawdust are the most suitable, giving the best results.

Another type of salmon smokehouse is a chamber 1.5 meters (5 ft.) wide and 3.5 meters (11.5 ft.) high and long. In one corner there is a door with dampers to draw off the smoke and steam. Two laths, one on each side, run the whole length of the room at a distance of from 6 to 8 inches from the ceiling. The ends of the smokesticks on which the salmon are hung, rest on these laths. A heap of oak chips is built down the middle line of the floor, for the length of the room. This is covered with oak sawdust and the whole smothered with ashes. The fire is lighted in the evening at the end near the door and during the night gradually burns the whole length of the room.

The temperature in either of these smokehouses should be about 20° C. (68° F.) or at the highest 25° C. (77° F.). A higher temperature makes the salmon flesh soft and pulpy, the flavor is not so good, and the flesh is difficult to cut. The fish are smoked from 3 to 5 days in either type of smokehouse, depending on the size of the fish and length of time for which preservation is desired. When the smoking is finished the sides of salmon are packed in shallow individual boxes lined with parchment or oiled paper. Three or four such boxes are packed in a tin-plate container which is afterward soldered shut.

Hard-Smoke or Indian-Cure Salmon

Some attempts have been made on the Pacific coast to prepare a heavily smoked and dried salmon known variously as hard-smoke, Indian cure or, in Alaska, as "beleke." Although it is superior in keeping quality and equal in flavor to salmon smoked by other methods, it has not met with much favor outside Alaska and the Puget Sound region as it is dull in color and hard in texture. Hard-smoke salmon makes an excellent appetizer or relish to be served with beverages, and there are possibilities of developing a better market. This product most closely resembles jerky (charqui) introduced to our western region by the early Spanish colonists.

Red and coho salmon are the species generally used in preparing Indian-cure salmon. Other species of salmon may be used, but only occasionally, when the more desirable types are lacking. Cobb (1930) states that the backs only are used which are cut into two or three long strips. The bellies are pickled and sold as salted bellies. Curers of beleke (hard-smoke salmon) have informed the author that, although this may be done, it is quite usual to smoke whole sides of salmon by this method.

If the bellies are to be utilized as pickled or hard-salted salmon, the remaining edible portion is split in two sides, the backbone is removed and each side is cut longitudinally into several strips. The strips may or may not be washed in a light brine. In some places sea water is used; in others, fresh water. The largest, thickest strips of back flesh are then placed in a tank of 90° salinometer brine; an hour later strips of medium size are put in, and after an interval of another hour, the smaller pieces. This procedure is followed so that all sizes will have the same degree of pickle. The strips are removed and drained after a period of 16 to 20 hours. If whole sides are to be used after cleaning and splitting, as described under the preparation of pickled salmon, the fish are washed thoroughly, drained, then brined overnight or for a period of 10 to 12 hours in a 90° brine.

After brining, whole sides are fixed on hangers, while strips are usually suspended by cords, run through one end as in smoking bacon at home. The fish are given an air drying of 24 hours to remove the surplus moisture. At the end of this time the salmon are placed in the smokehouse with the ventilators left open and the salmon are smoke cured over a fire of green alderwood. The smoking is done slowly at a low temperature of not more than 70° to 80° F. Two weeks is the average time required to smoke hard-cure salmon (beleke).

This product was first prepared around Kodiak, Alaska. Hard-smoked salmon is said to have better keeping qualities than other smoked fish, remaining in good condition for more than a year. If surface mold begins to appear in storage, the fish are taken out, scrubbed in brine, given an air drying of several hours, and then smoked for 24 to 48 hours, after which they are again stored in a cool, dry place.

Kippered Salmon

Kippered salmon probably has a larger sale than any other smoked fishery product on the Pacific coast. It is sold in a few large centers in the East and Middle West, but the great part is consumed in the western part of the United States. Practically all kippered salmon is prepared from white-fleshed chinook (king) salmon. This fish is not in so much demand in the fresh-fish market as other species, being considered inferior to the other salmon by reason of its paler color. It is equal to the brighter colored salmon in food value, however, and often has a better flavor. A constant supply of fresh fish at prices that will make a profit cannot be certain throughout the year, or for any season of the year, but frozen salmon is available the year-round, giving the curer an assured supply of raw material without wide fluctuations in price. Therefore, frozen salmon are used during a great part of the year and are split before they are completely thawed. Fresh salmon, being much softer in texture, require more care and skill in splitting, and the smoking period must be somewhat longer than if frozen fish are used.

The first step in the curing process is to thaw the salmon in tanks of cold water. In some establishments this is done with running water; in others, with standing water changed several times. The time required for thawing varies from 8 to 15 hours depending on the size of the fish, total amount in the tank, and whether or not running water is used. Smaller-sized fish placed in running water will be sufficiently thawed in 8 hours or less.

As the salmon have already been cleaned and dressed before freezing, they are split into sides. After the backbone has been removed, each side is cut into a number of smaller pieces. These pieces usually weigh about 1 pound each after curing and are separated according to thickness. There are usually three grades or sizes: chunks, the thicker part of the back flesh; thins, pieces of flesh not quite so thick; and strips, thin pieces from the bellies. The names used for the grades may vary with the locality and among different curers, but the separation into three grades is followed by practically all smoking establishments on the Pacific coast. The thinner pieces will cure more rapidly, which is one reason for separating them, while another is that the thicker pieces are considered better grade and bring a higher price. The third grade or size, for there is little difference in the quality, usually goes to the low-price markets. Fish smokers believe that the strips are the best kippered salmon.

The cut and sorted pieces of salmon are soaked in a 90° to 95° salinometer brine, for from ½ to 2½ hours depending on the size and thickness of the pieces, preference of the local market for which the salmon is destined, and on the time required for shipment. If the kippered salmon is to be shipped a considerable distance it receives a heavier brining since a longer period of preservation is necessary.

When sufficiently brined, the pieces are drained and then dipped into a tank or tub of coloring matter. The dye may be added to the brine, combining the two operations, in which case the amount of dye used is less than when the fish is colored by dipping. The dye most often employed is 150 Orange I, an aniline dye, the use of which is permitted under the United States Food, Drug and Cosmetic Act (Jarvis 1936b). Other red or orange dyes on the permitted list may be used. Where the fish are dipped in the dye after brining, experiments conducted at the College of Fisheries, University of Washington, indicate that dipping for 15 to 30 seconds in a solution made up in the proportion of one part of dye to 3,000 parts of water is sufficient. This is given only as a general formula, to guide those without practical experience. The curer must determine his requirements by experiment, and according to the desires of his customers as to the shade of color preferred. Anderson and Pederson (1947) state that for general purposes about 3 to 4 ounces of dye to 20 gallons of water should be used. The dye should first be dissolved in a small quantity of warm water, then added and mixed in the total volume of water. A dip of 15 to 30 seconds is sufficient. The flesh is dyed because of a popular prejudice against a lightly colored kippered salmon. The dye used is harmless and does not affect the quality of the fish in any way, while it does give it an attractive color. For certain markets, principally in States where all artificial food coloring is prohibited by law, no dye is used by Pacific coast smokers. Atlantic coast smokers rarely color kippered salmon.

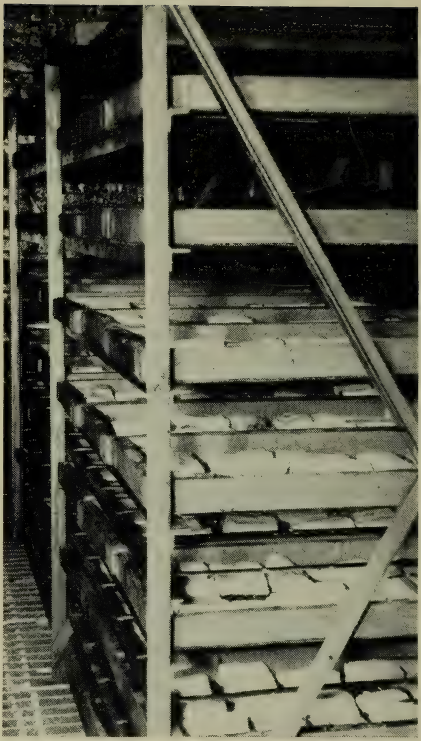

Figure 36.—Kippering salmon, Pacific coast: Movable racks with trays of salmon in the smokehouse.

When the salmon has drained for a short time, the pieces are placed on wire-mesh-bottomed trays, made of half-inch mesh, with two-inch wooden frames for sides (fig. 36). These trays should be thoroughly cleaned before use and the wire mesh rubbed with lard-oil or other edible oil to prevent pieces of fish from sticking to the wire. The pieces in any one tray are nearly as possible of the same size and thickness. They must not touch, or an even, sufficient cure will not be obtained. The individual trays are slid onto a rack holding several tiers of trays and moving on wheels. When filled, the rack is run into the smokehouse, or the trays may be placed directly in the smokehouse on fixed racks.

The pieces are allowed to drip for a few hours in the smokehouse, but a suggested procedure which would probably shorten this period and result in a better product would be to dry the trays of fish for an hour or two under a strong current of air at a temperature of about 70° F. When the excess moisture has drained away, the fire is lighted and the pieces are partially dried and smoked over a medium fire. The temperature in the section holding the fish should preferably be about 80° F. with 90° F. as a maximum, for from 7 to 13 hours. At the end of this time the fire is increased and the salmon are given a hot smoke by which they are partially cooked. Care must be taken that the fish do not get overheated for any length of time or they will be softened and spoiled.

Hot smoking or barbecuing takes 1 hour at a temperature of from 170° to 180° F. In some establishments the time is 25 to 35 minutes at a temperature around 250° F. When the fire is built up it must be regulated by means of drafts and ventilators so that the temperature will not be higher than desired.

When the smoking process is finished, the kippered salmon is thoroughly cooled before handling. In some cases this is done by throwing open the doors of the smokehouses. In other instances, where plants are equipped with movable smokehouse racks, the racks are run out on the floor and the fish are cooled under a current of air from a fan. The pieces are given individual wrappings of vegetable parchment and are then packed in a small box or basket. A container holding 10 pounds is the most popular size.

Kippered salmon is perishable, spoiling after exposure of a few days at ordinary temperatures, so if not to be sold immediately, it should be kept in chill storage at temperatures of 25° to 40° F. and retailed from refrigerated showcases. A certain amount of kippered salmon is intended for shipment to distant markets or is stored to fill rush orders. For these purposes it is frozen and held in storage for use as required. The freezing temperature and length of time required for freezing are the same as for fresh fish. As in freezing fresh fish, there is some variation in the temperatures in different plants but in a typical instance, kippered salmon is placed in the sharp freezer at −10° F. and left there for 10 to 12 hours. The storage temperature should be about 0° F.

SMOKED HADDOCK AND OTHER GROUNDFISH

The smoking of haddock has declined greatly in importance in the United States during the past 20 years. At the beginning of the century, with a much smaller population than now, the domestic production of smoked haddock or finnan haddie was approximately 5,000,000 pounds annually. Statistics show a production of 871,000 pounds of finnan haddie and smoked-haddock fillets in 1940 (Fiedler 1943). This is partly due to increased demand for fresh haddock, importation of finnan haddie from Canada, and failure of local curers to improve both product and marketing methods. In addition to haddock, varying quantities of cod, cusk, hake, and pollock fillets are smoked, using the same method and producing an article closely resembling smoked haddock fillets. The production of these smoked groundfish fillets amounted to 958,179 pounds in 1940. Some large flounder fillets and fillets of ling cod are given the same cure. nearly all of these products are known as finnan haddie in the retail market.

The smoking of haddock and related fish is much more important in the British Isles than in the United States, especially in Scotland, where more than half of the "whitefish" (cod, haddock, etc.) cured are smoked. Production of finnan haddie and smoked fillets, together with other smoked whitefish, amounts to more than 40,000,000 pounds annually. A great quantity of haddock is also smoked in England, Norway, Denmark, and Canada. Small amounts of smoked haddock are canned (Jarvis 1944a).

Finnan Haddie—American Method

The finnan haddie smoked in the United States is cured almost entirely in New York, Boston and Gloucester, Massachusetts, and Portland, Maine. From these ports it is shipped over the United States. Finnan haddie is also imported, largely from Nova Scotia, in amounts exceeding domestic production. Many customers prefer the imported fish because of its better color, texture, and flavor. Experience is required to prepare good finnan haddie and this applies to all groundfish given a finnan haddie cure. Besides knowing the essential points of the method, practical training is required to smoke a consistently good product.

When haddock are received at the smokery they are already split down the belly to the anal opening and are gutted, in other words, they are dressed as for the fresh-fish trade. The first step in the preparation of finnan haddie is to take off the heads, wash the fish thoroughly and clean out the black membrane lining the belly cavity, using a good stiff brush. Then the haddock are split down the belly side to within an inch or two of the tail. The knife should not go entirely through the fish. The cut is usually but not invariably made on the right side of the backbone. The fish should now lay out flat in one piece. The next step is to put the cleaned and split fish in a strong brine, testing at least 90° salinometer, for from 30 minutes to two hours. The brining time depends on the flavor demanded by the market for which the product is being cured, the atmospheric temperature and humidity, and the size and condition of the fish.

When sufficiently brined, the fish are taken from the brine and fastened to the sticks from which they are suspended in the smokehouse, the napes being stretched out flat and pierced by 2 nails fixed in the smokesticks. These sticks are about 2 inches square by 4 feet in length, and 3 fish are usually hung from each stick. In some establishments the sticks of fish are hung on the frames and left to dry in the air for a few hours. Other curing plants dry the fish for an hour or two with an electric or blower fan. If the haddock are hung in the smokehouse immediately, a fire should not be started until they have dripped or drained for several hours, or until surplus moisture is not apparent.

The smokehouses are generally like those for curing herring. Some curers are now beginning to use ovens of the type manufactured in the Middle West for curing bacon. The haddock are arranged in several tiers, one above the other. The important thing in hanging is to arrange each tier exactly below the one above, leaving enough space between sticks so that the smoke can circulate freely and all the fish will be evenly smoked.

At one time, the fuel used in smoking was oak but since it is scarce, almost any suitable hardwood is used, with rock maple or beech preferred. The smoking usually begins in the evening. A fire is started in the fire pit and allowed to burn for from 8 to 12 hours with dampers and ventilators open so that there is not too much smoke. Damp hardwood sawdust is then thrown on the fire so that a dense smoke is created. This is continued for the remainder of the cure. Where the smokehouse is not high, the smoking can be completed in as short a period as 5 hours. The temperature is raised during the second period of the smoke cure and kept as high as practicable without cooking or "scalding" the fish. The temperature should average about 80° F. in the second part of the smoke cure. Scalding depends to some extent on the amount of fish in the smokehouse, their moisture content, and distance hung from the fire. If a large amount of fish not well dried is hung in a house, it is much more apt to overheat. Small haddock are given a smoke cure totaling 6 to 7 hours.

When the smoking process is completed, the sticks of finnan haddie are removed to racks in the packing room where they are allowed to cool. If the fires in the smokehouse are extinguished and all doors or ventilators opened, the haddock can be left in the smokehouse until they are cool enough to handle. When cool, the finnan haddie is wrapped in vegetable parchment paper and packed in boxes holding 10 or 20 pounds.

Finnan haddie is usually shipped immediately by refrigerated express as it has a very short period of preservation. During warm weather, finnan haddie will keep for only a few days but in winter it may remain in good condition for 2 weeks. As a rule finnan haddie is cured from October to May. For holding over an extended period, the product is kept at a low temperature, usually about 36° F., although one of the largest Pacific coast dealers prefers 20° F., claiming that the finnan haddie is safe at that temperature, without damage to quality.

Scottish Method for Finnan Haddie

Smoked haddock or finnan haddie is said to have been originally prepared from dry salt haddock smoked in the fireplace chimneys of Scottish fishermen's cabins. According to one story, the discovery of this product was accidental. This account reports that salt haddock hung from the rafters for storage acquired a smoky flavor, which was relished. Smoked haddock began to be sold as a commercial product, resulting in the development of the present method of cure.

Finnan haddie was first prepared on a commercial scale about the middle of the eighteenth century. At first it was called "findon haddocks," deriving this name from the village of Findon in Scotland, where it was first prepared for market. The name has been shortened to that used at present. A complete description of the Scottish method of curing haddock is given by Duthie (1911). The outline of the Scottish method given here is a summary from that source, together with personal notes taken on a survey of the fish-curing centers of the British Isles.

The haddock may come to the curer in the round, that is, ungutted, or they may have been dressed on board the fishing vessel. If the fish have been previously gutted they have only to be headed when brought to the curing establishment. If not, they must first be eviscerated. The black belly membrane must be removed before washing. The haddock are thoroughly washed and freed from all traces of blood, slime, viscera, and "black skin" or belly membrane.

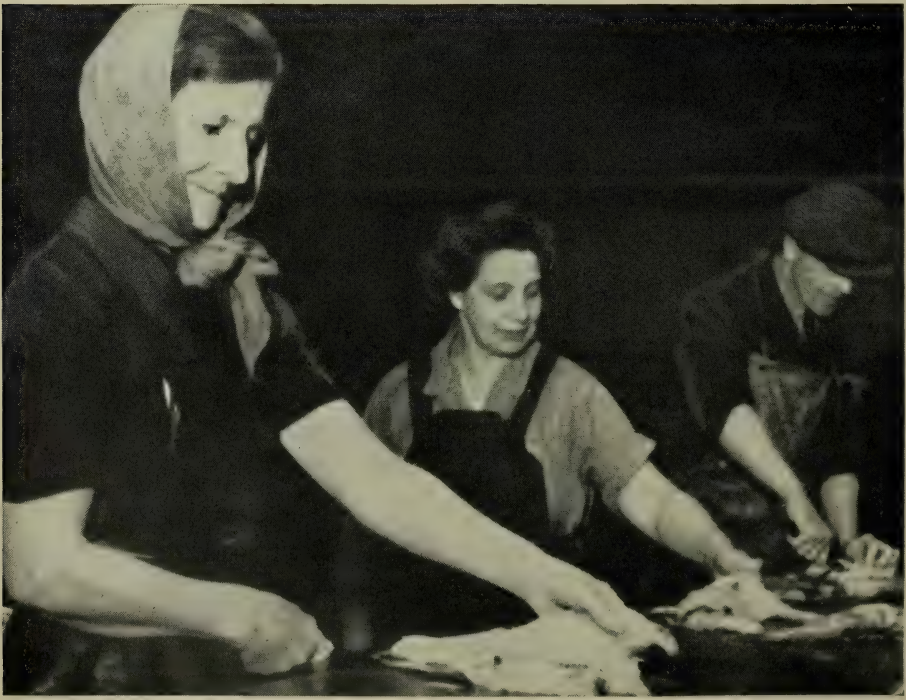

Figure 37.—Splitting haddock for finnan haddie. (Copyright photograph courtesy British Ministry of Food.)

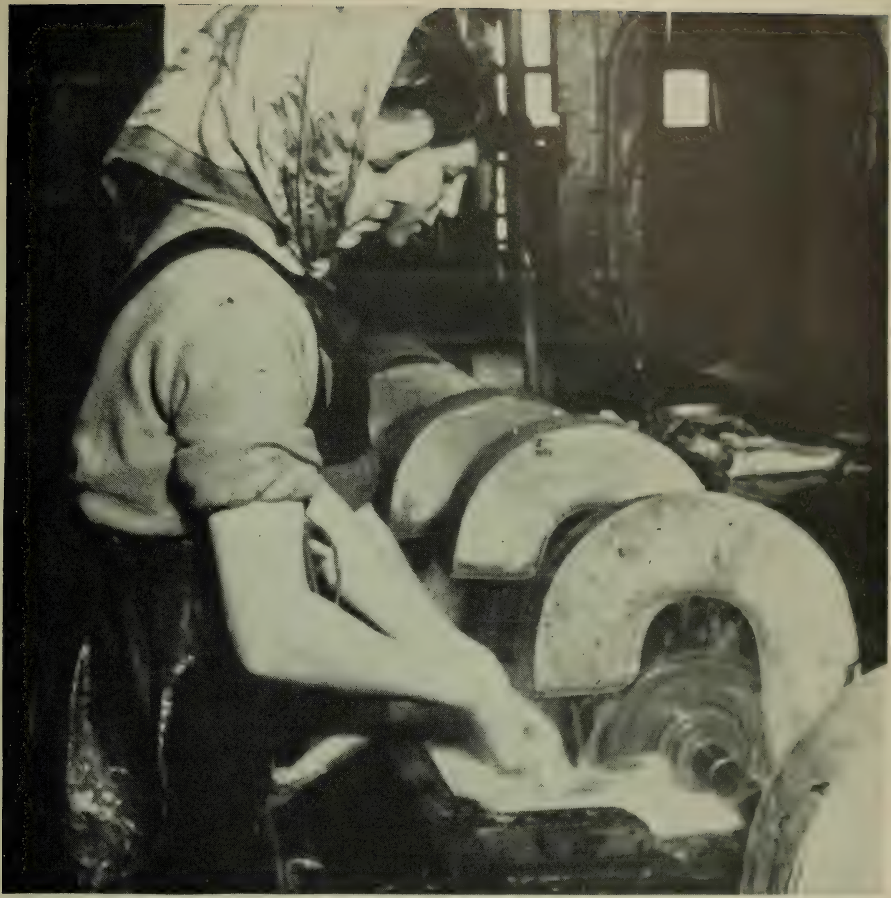

Figure 38.—Washing and cleaning haddock for finnan haddie. (Copyright photograph courtesy British Ministry of Food.)

After the fish have been washed, they pass to the splitter (fig. 37). The method of splitting is described by Duthie (1911) as follows: They are not split farther down than within an inch of the tail, and a cut is then made on the bone side of the fish. Entering the knife at the shoulder, the splitter makes a deep cut through the small bones to within an inch of the termination of the splitting. The object of this cut is to make the fish look broader. The haddocks as they are split are placed one by one upon a moving belt, two of which generally revolve from the center outwards towards opposite ends of the splitting table. The belt is usually so arranged that each haddock is deposited in a chute down which it slides into a receptacle at the end of the washing troughs. Here, a woman takes the fish and brings the blood-bone lightly into contact with a revolving brush, to clean the cavity (fig. 38).

After splitting and washing, the

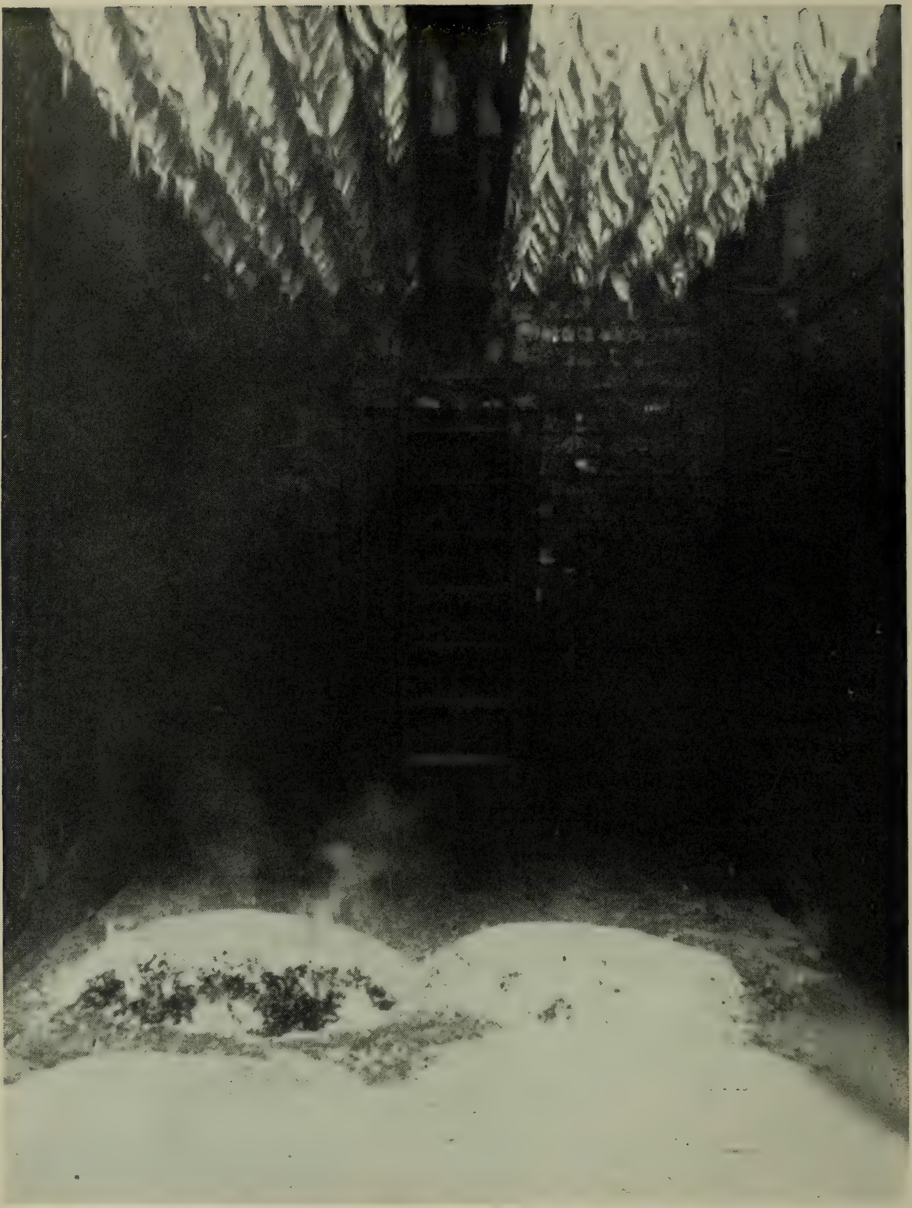

Figure 39.—Interior view of smokehouse during smoking of finnan haddie, showing the burning of sawdust and chips on fire-pit floor. (Copyright photograph courtesy British Ministry of Food.)

haddock are brined in a 90° to 95° salinometer brine, the time required varying from 20 to 30 minutes, according to the size of fish and market requirements. When they have been sufficiently brined, the haddock are laid upon drippers to drouth, that is, to drain and partially dry before hanging on the smokesticks. The drippers are drying racks, either portable or fixed. The fish are left to drain or dry overnight. In an emergency the fish might be hung immediately after brining, but if this is done they are more apt to fall from the smokesticks than if given a drouthing or drying. At all smokehouses visited in Scotland, the fish were hung on the smokesticks directly from the brine tub and given some draining and drying on the stick before being hung in the smokehouse (fig. 39).

A specially constructed smokehouse or finnan kiln is described by Duthie (1911). However, a smokehouse of ordinary type, intended for smoking herring, may be, and often is used for this purpose although haddock must be hung at a lower level than other fish. Practically all smokehouses observed in Scotland curing finnan haddie were of the same type as for kippered herring, sometimes called the "North kiln." The special type apparently is not used so widely as formerly. The lowest tier of fish is hung about 2 feet above the fire in the special finnan kiln described by Duthie. A mixture of peat and softwood sawdust is the fuel used for smoking as a dense cloud of smoke is required to color the haddock. Most of the plants observed by the writer in Scotland did not use peat for fuel but used hardwood or white-wood chips and sawdust. The fish were dyed with annattor before drying to impart the necessary color. As the lowest tiers are hung very near the fire, close watch must be kept to prevent cooking or scalding. The haddock nearest the fire are transfered to the top rows and vice versa during the process in order that the product may be evenly cured. The time required for smoking varies from 5 to 8 hours as determined by weather conditions, size of fish, and market preference. The haddock and other whitefish hang about 8 feet from the fire in the North kiln.

The finnan haddie are taken out of the smokehouse at the end of the cure and allowed to cool. When sufficiently cool they are rinsed in a weak brine solution to remove any sawdust and ashes from the fish. In Great Britain, finnan haddies are marketed in boxes holding from 14 to 140 pounds of fish. The most popular size in the trade is said to be the 2-stone box, a container with a capacity of 28 pounds.

Smokies

Haddock too small for curing as finnan haddie, and other small fish, are sometimes made into "smokies" in Scotland. Smokies are a hot-smoked product. No cooking is required. Smokies are also prepared in the Boston area of the United States at a rate of about 30,000 pounds annually. Smokies would have a much wider sale if the public were made acquainted with them by market development advertising.

Small haddock are headed, gutted, and washed in the usual way, but not split. After draining a few minutes they are brined in a 90° to 95° salinometer brine, for 30 to 45 minutes. The brined fish are tied together in pairs by a loop of string twisted around their tails and hung one on each side of a triangular tenter or smoke stick, such as are used in smoking fillets. The sticks of fish are set out to drain off the surplus moisture. About 2 hours will be required for this step, unless the weather is humid and without much breeze, when more time will be necessary.

The smokehouse or kiln may be built in either of two ways. One way is to sink a pit into the ground, lining the walls and bottom with brick. The other kiln is a brick or sheet metal tank built above the ground, with two or three ventilating holes near the ground. The second type is most widely used. The size of the kiln varies according to the requirements. The average dimensions are 12 feet long by 6 feet wide and 4 feet high. A barrel-type smokehouse might be utilized for curing a few fish by this method.

Small chunks of beechwood are the favorite fuel for smoking. A fire is built up over the whole floor of the kiln and allowed to burn brightly, when enough beechwood sawdust is thrown on to give off a dense smoke. The sticks loaded with fish are set in place across the top of the kiln. A wooden framework cover is then set over the top of the kiln, which is then covered with moist sacks. It is important that the smokehouse be tightly covered, so that smoke and heat cannot escape. Smoking is a rapid process, and the kiln requires little or no attention during the cure. The fish are taken out, practically cooked as well as smoked, in from 25 to 45 minutes, sometimes a little longer if the fish are larger than usual. Smokies are brown-skinned when cured. They are allowed to cool before being packed in small paper-lined wooden boxes. In Scotland the boxes hold one stone (14 lb.) of fish while in Boston the capacity is 10 pounds. Like all hot-smoked products, smokies can be held for only a short time.

Smoked Fillets

Smoked fish fillets are fairly well known to the American market where they are often marketed under the name of "boneless finnan haddie." In Great Britain almost any white-fleshed, lean fish, producing fillets of a suitable size, may be cured by this method according to statements made by different fish-curers in interviews with the writer. The method used in England and Scotland is thought worthy of description. It is about the same as that used in the United States and Canada.

The fish are cut into fillets, skinned, and washed. After draining the fillets about 30 minutes, they are placed in a strong brine solution testing about 90° salinometer. The exact time required for brining is said to be determined only by experience and depends on the market for the product. For the British trade it is about a half hour as the average. In the United States fillets are brined from 20 minutes to 2 hours but usually about 1 hour. In Canada, the time varies from 20 to 30 minutes. After draining off the brine, the fillets are dyed. The dye used is annatto, previously mentioned as being used for coloring kippered herring and finnan haddie. The deepness of color given to the fish depends on the trade requirements. Some markets demand a fairly lightly colored fish, a shade that might be called straw color while others insist on a deeper shade.

The dye is usually made up in the proportion of one-fourth gallon of dye solution to a bucket of water. In the United States almost any of the colors giving a yellow shade and which are permitted under the Food, Drug and Cosmetics Act, may be used, except in States where all artificial food colors are forbidden. In some cases, the fish are both brined and dyed in the same operation. If this is done, the dye solution is weaker. Some curers dye the fish before putting them in brine solution. A stronger dye solution is used when the fillets are not brined and dyed in a single operation. They are dipped and withdrawn immediately.

Fresh fillets are not hung on smokesticks like other fish, but hung over triangular wooden tenters or smokesticks, or stretched across a pair of iron rods or arranged on trays with a wire-mesh bottom and wooden frame. They are allowed to drip or drain.

The fire is usually lighted in the evening and the fillets are lightly smoked and dried for a total of from 5 to 11 hours. As a rule they are cured over a clear fire with little smoke for 2 or 3 hours, after which they are given a dense smoke for about 3 hours longer. In the United States, the brined and dyed fillets are dried in a current of air, until a thin shiny pellicle or film forms on the surface. This usually requires about 2 hours. The fillets are then hung over three-sided smokesticks, each side being about 3 inches in width, or arranged in wire-mesh trays. The fillets are then cured over a fairly light smoke for 4 hours at a temperature not higher than 90° F. The fillets are then turned so that the side previously resting on the smokestick is uppermost and they are smoked 4 hours longer in a light smoke. The fire is then smothered so that a dense cloud of smoke is obtained, and the fillets are smoked until they are a deep straw color. The fillets are turned once or twice so that both sides will be evenly colored. This operation will take from 4 to 6 hours and the method is used where artificial color is forbidden.

In Great Britain, the fillets, after cooling, are packed in paper lined boxes with average net contents of about a stone (14 lb.) of fish. In America, boxes containing 10 and 20 pounds are used. Smoked fillets must not be overheated or smoked in such a way that they acquire a leathery texture. They should be smoked and salted only to the degree required to obtain the desired flavor, without drying out the moisture contained in the interior. Fillets must be stored at the same temperature as finnan haddie, if they are to be held any length of time.

MISCELLANEOUS FISH SMOKING

Alewives

Considerable quantities of river herring or alewives were smoked at one time, principally for export to the West Indies. Stevenson estimated the annual production at 5,000,000 pounds in 1899. There was also a local commercial trade in the Delaware and Hudson River areas, and in Maryland, Virginia, and North Carolina. The export trade has disappeared entirely and local commercial curing has decreased greatly. Fishermen and farmers cure quantities of river herring annually for their own use and for sale but the production is scattered. As much of the production does not appear in the statistical reports, it is difficult to estimate the quantity smoked. It is believed to be about 500,000 pounds. Most of the alewife or river herring smoking is now done in the Chesapeake Bay region of Maryland and Virginia, and in North Carolina. The smoking season is in April, May, and June.

The fresh alewives are washed thoroughly and scaled, as soon as possible after catching. When the washed fish have drained for a few minutes they are put in a tank of 90° salinometer brine. Some salt is scattered over the surface, to strengthen the brine as it becomes diluted. The fish are usually left in brine overnight or for a total of about 12 hours. In the morning the alewives are strung on smokesticks. The stick is inserted through the left gill cover and out the mouth as is done in smoking sea herring. After the alewives are strung on sticks they are dipped in fresh water to rinse them off. The sticks are then placed on racks where there is a good current of air and are allowed to drip and dry until no moisture is apparent on the surface. Drying will require from 2 to 8 hours. The sticks are then hung at a minimum distance of 6 to 8 feet from the fire in a smokehouse of the type used for smoking sea herring except that it is much smaller. The alewives are smoked in a dense cold smoke from pine shavings, corncobs or similar material for 48 to 72 hours. The temperature should not be much over 70° F. If the fire is allowed to become too hot, the fish are apt to crack or fall to the ground.

Alewives smoked as described here will keep for about 30 days in the spring and from 10 to 14 days in summer. The shrinkage is not great as the fish are not eviscerated. The curer should obtain about 85 pounds of smoked alewives from 100 pounds of the round fish.

A different method is followed in some New England sections. The fish are roused in fresh water but little attention is paid to scaling, as it is claimed that most of the scales will come off in the curing process. The fish are then mixed with salt and the brine is allowed to form naturally. About 25 pounds of salt are used to 100 pounds of fish. The alewives remain in pickle from 3 to 5 days. They are then soaked in fresh water for 4 to 5 hours, and strung on smokesticks, as described for sea herring. After drying for a few hours the alewives are hung in the smokehouse where they are smoked over a low smoldering fire of hardwood and sawdust for 4 to 5 days. When the New England alewives were exported to the West Indies, smoking required 2 weeks.

In the Baltimore area and a few other Maryland localities some alewives are smoked as follows: The fresh fish are gibbed like Scotch cured herring, scaled roughly, washed in fresh water and then left for 3 hours in a 90° salinometer brine. When sufficiently brined, they are strung on thin iron rods by piercing the point of the rod through the eye sockets of the fish. The sticks are hung to drain for about 2 hours at the breeziest point around the establishment.

They are then hung in smokehouses made of hogsheads, with a pit below. A fire made of equal quantities of oak and hickory wood is lighted. The fish are allowed to dry over a clear fire for a few minutes. The top is then covered with dampened sacks or old carpet. This is kept moist during the smoking by sprinkling occasionally with water. The fish are cured in steam and smoke for 3 hours, at a temperature of around 170° F. If the temperature goes too high, above 200° F., the fish are apt to drop into the fire. If the fire becomes too hot, it is smothered with hardwood sawdust. The finished product may be eaten without further preparation, as it is cooked as well as smoked. It keeps only a few days after smoking.

Bluefish, Butterfish, Croakers, Flounder, Shad, and Striped Bass

Varying quantities of bluefish, butterfish, croaker, flounder, shad, striped bass, yellow perch, yellow pike, and other miscellaneous species are smoked from time to time. In fact, if the curer is experienced and the proper method is used almost any species of fish may be smoked to make a palatable product. As most of these fish are prepared in small commercial quantities by methods similar to those already described, they are discussed together in the following section.

The butterfish (*Poronotus triacanthus*) is a small food fish with a deep body, so that it looks almost round. Because of its shape and bright silvery color, it is given the secondary common names of "dollar fish" and "pumpkin-seed." The butterfish is taken commercially mostly in the Middle Atlantic States. It is caught largely in traps and pound nets, but also to some extent by seines. Statistics show a production of 480,700 pounds of smoked butterfish in 1940. The butterfish are washed but not gutted. They are brined from 2 to 6 hours in a 90° salinometer salt solution. The fish are then strung on smoking rods, usually run through the eye sockets. After draining and drying for a few hours, the butterfish are hung in the smokehouse where they are cured in a cool smoke for 4 to 5 hours. When the fish have the desired amount of color, the fire is built up and they are hot smoked at around 200° F. for about one hour.

The croaker (*Micropogon undulatus*) is one of the common marine food fish from the Middle Atlantic States to the Gulf of Mexico. It averages about 10 inches in length and has an average weight of ½ to 1½ pounds, depending on locality. The maximum weight is from 3 to 4 pounds. The croaker is taken mostly in pound nets, haul seines, and otter trawls, and to some extent by hand lines and miscellaneous gear. It has a lean, white, firm flesh.

The larger croakers are smoked occasionally. The head is removed, retaining the collar bones. A cut is made down the belly to the vent and all viscera or other offal are removed from the body cavity which is scraped and cleaned thoroughly. Then the fish are split down the belly side to within an inch or two of the tail. The knife should not go all the way through the fish. After the croakers are cleaned they are washed, then placed in a strong brine from 30 minutes to one hour. The brined fish are fastened to smokesticks as in curing finnan haddie, so as to lay out flat in one piece. They are dried for a few hours. The drying process is shortened and standardized by using an electric or blower fan. The sticks of fish are then hung in a smokehouse and given a cool smoke of light density from 2 to 4 hours. The fire is then covered with sawdust and the croakers are held about 2 hours longer in a dense smoke. The temperature should not be higher than 100° F.

The flounders (Pleuronectidae) include a variety of species of flatfish. These are fish with the body much compressed, both eyes on one side of the head, with the blind side colorless and usually the underside in the water. The two most important commercial species on the American coast are the winter flounder and the summer flounder. The average weight is from ½ to 3 pounds, but they may weigh up to 15 pounds. They are caught mostly by otter-trawls, line-trawls, and handline. Small flounders, those weighing about ½ pound, are gutted, washed, and brined in a 90° salinometer salt solution for 2 hours. They are then strung on smokesticks, drained, and air-dried for a few hours. They are cold smoked for 8 to 10 hours. Some smokers then build up the fire and give the flounders an additional hot smoking at 200° F. for about 30 minutes. Large flounders are cut into fillets which are smoked in the same way as cod and haddock fillets.

The shad (*Alosa sapidissima*) is an important food fish on both Atlantic and Pacific coasts, but the largest fisheries are in the Middle Atlantic and Chesapeake Bay areas. The average weight is 3 pounds for buck shad and 4¾ pounds for roe shad, with a maximum of 15 pounds for the species. Shad are caught mostly in pound nets, traps, and seines. Some shad are smoked in the Chesapeake Bay region. The method is much the same as for croakers. Some smokers dry and color the fish by cold smoking, then hot smoke and cook them for about an hour. This is also the method usually followed in smoking the bluefish (*Pomatomus saltatrix*). The method used for smoking shad on the Pacific coast is much the same as for salmon. Some shad are lightly smoked or kippered and canned on the Columbia River. This is described in detail elsewhere (Jarvis 1944a).

The striped bass (*Roccus saxatilis*) is a favorite food fish of the Atlantic coast. It has also been introduced to the Pacific where it is now quite common especially in the San Francisco Bay area. It is especially abundant from Massachusetts to North Carolina. The usual weight is from 3 to 5 pounds. Striped bass are taken in traps, pound nets, gill nets, seines, and by hook and line.

The striped bass is occasionally smoked with good results, using the finnan haddie cure. It has also been smoked like salmon after first curing in a salt-sugar-spice mixture.

The Florida sailfish (*Istiophorus volador*) is usually regarded as a sport fish and is taken by trolling. Some of the catch brought in to ports in southern Florida is smoked, using the method as outlined for sturgeon and catfish.

Carp

Carp (*Cyprinus carpio*) is one of the less important smoked products. It is an under-utilized fresh-water species which makes a smoked product of good quality and could be prepared in much greater quantity, especially in the North Central States, if some effort was devoted to market development. Production is apparently increasing slowly. Statistics indicate a production of 106,000 pounds in 1930, 116,000 pounds in 1935, and 173,000 pounds in 1940.

There is considerable variation in commercial methods of smoking carp but the following description may be considered typical: The fish are headed, gutted and cleaned thoroughly, then cut in steaks or chunks weighing from ½ to 1 pound each. The steaks are brined for 10 to 12 hours in a brine testing from 60° to 70° salinometer. The length of time varies with the size and condition of the pieces. Fish not in best condition are given a heavier brining for a longer period.

In some instances, the pieces are hung on smokesticks; in others, they are placed on wire-mesh-bottomed trays, previously oiled to prevent the fish from sticking. Some smokers then sprinkle the fish with spices and condiments, such as red pepper, poppy seeds, cloves, or bay leaves.

The chunks of carp are then placed in the smokehouse for a period averaging 3 hours and cooked or "dried" over a hot fire without much smoke. The temperature in the smokehouse during this period is about 225° F. The fire is then broken down and dampened with sawdust to build up a dense smoke. The carp pieces are then smoked for about an hour at a temperature ranging from 90° to 110° F., which should give sufficient color and flavor. When the fish has cooled, the pieces are wrapped in parchment paper and packed in boxes.

Catfish and Paddlefish

Other fish are sometimes smoked as a substitute for sturgeon. Two species are so cured, the channel catfish (*Ictalurus lacustris*) and the paddlefish or spoonbill catfish (*Polyodon spathula*). The annual production is about 10,000 pounds of the former and 150,000 pounds of the latter species. The fish are taken in the lower Mississippi River, and most of the smoking is done at St. Louis and Chicago. Most are taken by set lines, though some are caught in haul seines.

Since catfish were first smoked as a substitute for smoked sturgeon they are cured by the same method as sturgeon. The fish usually come to the smokehouse from the fresh-fish dealers already gutted and without heads. As the first step in preparation, the fish are skinned and cut into chunks weighing about 1 or 1½ pounds each. The pieces are washed, then brined or pickled in tubs for 6 to 8 hours. Brining may be done in either of two ways: The pieces may be rubbed with salt and packed in a tub with more salt scattered over them, where they are allowed to form their own brine, or they may be placed in a strong brine (about 90° salinometer) at once. When the pieces have been sufficiently brined they are rinsed in fresh water to remove surplus salt or other foreign materials. Then they are strung on smokesticks or placed in wire-mesh bottomed trays, after which they are air-dried for 2 hours. The fish are then placed in the smokehouse to be smoked for 8 to 9 hours in the same way that sturgeon is smoked. One hundred pounds of dressed catfish yield 65 to 70 pounds of the smoked product.

At various points in the Mississippi Valley and Great Lakes areas, small catfish (*Ameiurus* sp.) are smoked whole, like lake herring. They are split to the vent and eviscerated. The head and, in some instances, the skin, are left on. The fish are mixed with salt and left in tubs to brine. When sufficiently struck, they are smoked for a few hours following the procedure described for lake herring. Most of the small catfish smoked are prepared by individuals for home use, and only small amounts are cured commercially.

Eels

Smoked eel has always been considered one of the most important smoked-fish products in Germany. Large amounts of eels were imported into Germany from Denmark and other European countries, and even from Egypt. Smoked eel is also a favorite smoked-fish product in the Netherlands. The smoking of eels is said to have been introduced into the United States by early Dutch colonists, but the greatest demand in this country has come at a comparatively late date from the people of German and other North European stock. In the United States, eels are smoked principally in New York, Philadelphia, Chicago, and Milwaukee. The production varies between 100,000 and 300,000 pounds annually. The amount smoked was 225,000 pounds in 1940.

The common eel (*Anguilla bostoniensis*) is widely distributed, being found along the Atlantic coast from Canada to Key West. It may be distinguished by the slender snake-like form of body, the low vertical fins, devoid of spines, and the absence of ventral fins. The common or fresh-water eel varies in length from 2 to 3½ feet and reaches a maximum weight of 16½ pounds.

Eels are caught in eel pots, which are small cylindrical traps, usually made of heavy galvanized wire screen with a ¼- or ½-inch mesh, and funnels. The traps are anchored on the bottom of a stream moored to a line or with a float to mark the location. Eels are also caught by spearing. This is usually done at night. The fisherman carries a torch or lantern, which attracts and dazes the fish, making it compartively easy to spear. Eels are taken to some extent with handlines, trawl lines, fyke nets, pound nets, haul seines or drag nets, otter trawls, and floating traps.

Some eels are received fresh but probably the greatest quantity come to the smokehouse frozen. If frozen, they must be defrosted by soaking in a tank of cold water for 4 to 10 hours, depending on size. The eels are dressed after the surface slime is removed by scraping or rubbing with fine salt. They are split down the belly from the head past the vent and eviscerated. If possible, the large vein along the backbone should be pulled or cut out. The larger eels are cut into cross-sections from 1 to 2 inches thick.

The eels may be given the proper amount of salt cure by rubbing in dry salt, then placing them in a tub and allowing the brine to form naturally, or they may be placed in 100° salinometer brine. As with other smoked products, the length of time in brine depends on the weather, method of salting, length of preservation desired, and local market preference. Eels may be in brine from 2 to 24 hours.

Dry salting requires less time than brine salting. A German reference gives the time as 5 or 6 hours (Hoffman; undated). Tressler (1923) reports it is about 24 hours. Stevenson (1899) states that about 7 hours are used in the Great Lakes areas, 2 hours in New York.

On removal from the brine, the eels are rinsed in fresh water to remove any surplus salt or slime. Sometimes they are scrubbed with a stiff-bristle brush. The fish are next strung on iron rods about ¼-inch thick, the rod passing through the head of each eel, or through the throat cartilage and out of the mouth. In other establishments, the eels may be pierced through the head, twisted around the rod, and pierced again through the body near the tail. If the eels are large and have been cut in sections, the pieces are arranged on wire-mesh-bottomed trays, which have been oiled to prevent sticking. Some spices such as caraway, peppers, bay leaf, coriander or cardamom seed, or a combination of several of these, may be scattered on top of the slices. If possible, the eels should be dried in the open air for a few hours but if this is not practicable they may be dried off by fans.

There is also great variation in the smoking procedure. Some eels are smoked for 2 or 3 hours over a low, clear fire without much smoke. Then a hot fire is built up, covered with sawdust to make a dense cloud of smoke and the eels are hot-smoked and partly cooked for 2 hours longer. Other curers hot-smoke the eels over a hot fire of corn cobs until they are nearly cooked; then the fire is partially smothered with sawdust which produces a dense smoke that colors and partially dries the eels. In some Middle West smokehouses, smoking is done at an even temperature near 100° F. for 6 to 8 hours. In one or two eastern centers, the eels are given a mild smoke for 4 or 5 hours until they have acquired the proper color, when the fire is built up and the eels are hot-smoked or cooked for 30 minutes at about 240° F.

One of the methods for smoking eels followed in northern Europe, especially Germany, is somewhat different from methods described previously. The head, skin, tail, and viscera are removed, and the eel is split lengthwise into two fillets, removing the backbone, with many of the small rib bones attached. The fillets are then covered with a strong brine (about 90° salinometer) where they are left for 6 hours. They are then wiped dry with a clean towel and covered with the following preparation, which has been pounded into a paste in a mortar: one large anchovy, 1 ounce of fine salt, 8 ounces of powdered sugar, 1 ounce of saltpeter, and sufficient butter to make a smooth paste of the ingredients. The eel fillets are coated with this preparation, then rolled up tightly in the form of a cylinder, beginning with the tail end. The cylinders are tied in the middle with a cord to hold them together. They are then sewed up in a cloth which covers the sides and allows the end to project. These cylinders are hung in an ordinary smokehouse where they are cured in a cool, dense smoke for 5 to 6 days. After cooling they are ready for market.

Eels are smoked and marinated in Italy and Dalmatia by the following method: The eels are thorougly cleaned, headed, and skinned. Larger eels are cut in slices. The eels are then fixed on spits, or if sliced, arranged on trays, and smoked over a hot fire of oak and ash wood for 40 minutes at a temperature of about 225° F. When the eels are cooled they are packed in kegs, holding from 25 kilograms (55 pounds) to 55 kilograms (121 lb.). Spices, principally bay leaves, whole peppers and cloves, are scattered between the layers of fish. When the container is full, a solution of 6 percent wine vinegar and 3 percent salt is poured in until the keg will hold no more. This preparation is known as "Comacchio" type eels (Jacobsen 1926).

Goosefish

The goosefish (*Lophius piscatorius*) is a large, sluggish fish found on the North Atlantic coast from Nova Scotia to Cape Hatteras. Local names are anglerfish, monkfish, and allmouth. It reaches a length of 4 feet and a weight of 40 pounds. Although palatable and a good food fish, most of these fish are thrown back after removal from the nets. Statistics give the catch as 104,000 pounds in 1943. The goosefish or angler has not heretofore been prepared as a commercial smoked-fish product. A method has been developed by the U. S. Fish and Wildlife Service. As a result, hot-smoked angler is now being sold on a small scale in the New York market. It is an appetizing article which should find a wider sale, if aided by market-development work.

The fish are landed, headed, and eviscerated. The first operation at the curing plant is to wash the fish thoroughly in fresh water to remove slime, after which they are skinned. The flesh is removed in two fillets by cutting along both sides of the backbone from head to tail. The fillets are cut into portions which weigh approximately 1 pound each after smoking. These portions are placed in a 50° salinometer brine where they are left from 16 to 20 hours. The length of time depends on the thickness of the pieces, the preference of the trade for which the fish is being cured, and weather conditions. After salting, the pieces are freshened in cold running water for 30 to 60 minutes and are spread on wire-mesh-bottomed trays brushed with edible oil to prevent the fish from sticking. Pepper, garlic salt, or other condiments to suit the taste are sometimes sprinkled on the fish before drying.

The fish are dried in a current of air at about 70° F. until all surface moisture has disappeared and a thin skin or pellicle has formed. The trays are then stacked in the smokehouse. The fish are cooked for 4 hours, the temperature being raised slowly to avoid case-hardening, and then maintained at 170° to 180° F. A heavy smoke is then started, using oak sawdust for fuel and the cure is continued for another 1½ hours at the same temperature. The fish should then have the desired flavor, color, and texture. The doors of the smokehouse are opened immediately and when the fish is cool enough to handle the chunks are wrapped in cellophane or vegetable parchment and stored under refrigeration until sold. Hot-smoked anglerfish is similar to other hot-smoked fish products in appearance and uses.

Halibut

Smoked Atlantic halibut (*Hippoglossus hippoglossus*), today a product of minor importance, is mostly cured on order for a limited market. At one time it was an important cured fishery product. According to Stevenson (1899), 3,000,000 pounds of halibut were smoked in the United States in 1872, and the annual production averaged 2,000,000 pounds in the latter part of the 19th century. The annual output today probably does not amount to more than 15,000 pounds.

There are several reasons for the great decline in the preparation of smoked halibut: First, the depletion of the Atlantic halibut fishery, now at only a small fraction of its former level; second, long voyages are no longer made to Davis Straits and Greenland to salt halibut, which was the source of raw material for most of the smoked halibut; third, the development of freezing has made available a better method of preservation; and fourth, the price of fresh halibut has been so high that curers can rarely afford to smoke it. Most of the halibut is taken by trawl line (long line); some is taken by hand line and otter trawl incidental to other fisheries.

As salted halibut is not ordinarily available today, smoked halibut usually is prepared from fresh fish. As the first step, the halibut is cut into "fletches" or strips of boneless flesh, with each side cut into two fletches. The fletches are thoroughly washed, drained for a short time, then salted down in butts like those used in curing codfish. The strips are rolled in salt and packed in like codfish, skin side down, except for the top layer, with a scattering of salt between each layer of fish. The brine is allowed to form naturally. If the amount of brine is insufficient, 100° salinometer (saturated) brine may be added. After one or two weeks, the fletches may be taken out and kenched, or may be allowed to remain in the butts until ready for smoking. Approximately 10 days are required for the salt to strike through or salt cure the flesh.

When the halibut are to be smoked the fletches are taken out of salt, washed thoroughly, and scrubbed with bristle brushes to remove encrusted salt. They are then placed to soak in fresh water for 3 or 4 hours. The water is then changed and the halibut are again soaked for about the same length of time. Soaking removes excess salt and softens the flesh for smoking. At the end of the soaking period the fletches are water horsed for 5 or 6 hours, that is, piled in stacks or kenches, skin side up, and weighted down heavily to press out moisture. After water horsing, the fletches of halibut are spread out on flakes like those used for drying codfish. Here they are sun-dried for a total of 24 hours with the drying time spread out over 3 or 4 days, or even longer if the weather is unfavorable. The fish are placed in small piles and covered with flake boxes during the night or in rainy weather. After drying, the fletches are cut in small pieces, from 2 to 6 pieces to the fletch, with a gash in each piece where the flesh is thin and the skin appears tough.

The fletches are then usually strung on smooth, round, hardwood sticks about 2 feet long and ¾-inch in diameter, though sometimes rods of thick steel wire 3½ feet long are used. These rods are passed through the gashes in the chunks of halibut. From 5 to 7 pieces are hung on sticks 2 feet long, and from 8 to 12 on 3½-foot rods. The pieces are spaced 2 or 3 inches apart so that the smoke will penetrate and color evenly. The sticks when loaded are passed into the smokehouse, which is of the standard type, such as is used in smoking salmon or herring. Practically all of the halibut smoking is done in Gloucester, Mass.

Oak chips or sawdust are preferred as fuel for smoking. Chips are generally used in starting the fires, with sawdust to smother the flames. Fires are built along the two long side walls of the fire pit, leaving the middle empty. They are kept going until the smoke cure is complete, which requires from 2 to 5 days, depending on the weather and the size of the pieces. Doors and ventilators are left slightly open so that there will be a constant circulation of air since for a good cure halibut must be kept cool and as dry as possible. It also takes the smoke better under this arrangement. The loss in weight is about 70 percent. A halibut weighing 100 pounds round weight will yield 30 pounds of the finished product. A good smoked halibut should have a straw-yellow color. Most of the halibut now smoked are cut in small strips and packed in glass tumblers to a net weight of about 5 ounces. Metal tops are vacuum sealed on the containers, which are not heat processed.

Kingfish and Spanish Mackerel

The kingfish, or king mackerel (*Scomberomorus cavalla*) also known as the cero or painted mackerel, is one of the choicest food fish of the South Atlantic and Gulf Coast regions. It is sometimes smoked as far north as Morehead City, N. C. Regular commercial production is confined to Florida where it is cured by fishermen for local sale. Kingfish are taken mostly by trolling lines, though some catches are made by run-around gill nets, haul seines, and hand lines.

As soon as possible after landing the kingfish are cut into two sides, removing the backbone. The sides are washed thoroughly, drained for a few minutes, then placed for about one hour in a 40° salinometer brine which is chilled with ice. The object of this step is to leach diffused blood from the flesh, and to make the flesh firmer for handling during curing. The brined kingfish are drained for a few minutes, then dredged in packers fine salt in a shallow box. Some salt is rubbed gently into the flesh. The sides are picked up with as much salt as will cling, then laid in a box. They are left in salt from one to two hours, depending on the size of the fish, and the weather. If the sides are large and the weather humid, the longer salting is followed.

When it is judged that the fish has enough salt the sides are washed in fresh water, to remove all traces of salt, then fixed on hangers and dried in a current of air, either from a fan or in a good breeze. The kingfish are dried until no surface moisture is apparent, and preferably until a thin shiny skin has formed on the surface. The sides are then hung in the smokehouse, from 4 to 6 feet above the ground.

A low fire of dry hardwood is lighted with the smokehouse ventilators open, and the fish is cured without much smoke for 24 to 36 hours. The ventilators are then closed, the fire is smothered with hardwood chips, sawdust or bark, and a dense smoke is built up. The kingfish are cured in this smoke from 6 to 12 hours, depending on the color and flavor preferred. Some consumers prefer a lighter color and flavor, others a glossy brown color and pronounced smoke flavor. Some curers brush the flesh surface of the sides with vegetable oil just before making the dense smoke. This is to help in giving the desired glossy appearance. The temperature of the smokehouse should be kept below 90° F. After cooling, the sides are wrapped in oiled or parchment paper and packed in light wooden boxes. Smoked kingfish are cut into thin slices like smoked salmon, and the slices are sometimes grilled like ham or bacon.

The above method is also used in curing Spanish mackerel (*Scomberomorus maculatus*). If mackerel are being cured, the salting period is from 30 to 60 minutes, the initial period of the smoke cure from 8 to 12 hours, and the final portion in dense smoke from 2 to 4 hours.

Spanish mackerel and occasionally kingfish are also hot smoked, giving a product that is preferred by many consumers as it requires no additional cooking or preparation. The mackerel are split into sides. Sometimes, especially with larger fish, the backbone is removed. The fish are washed and soaked to remove blood, as described above. A brine is then prepared in the following proportions: 2 pounds salt; 1 pound sugar; ½ ounce saltpeter; 1 ounce crushed whole black peppers; 1 ounce crushed cardamom seeds; and ½ ounce crushed bay leaves. The ingredients are made into a brine that will test about 90° salinometer, or by the more usual local method, a brine that will float a potato. The amount of ingredients is increased according to the quantity of fish cured. Various spice mixtures are used, changing variety and quantity according to personal preference.

The mackerel are left in this brine for 2 to 4 hours depending on the size and thickness of the fish, the amount of fat, and individual preference. Some consumers require a less salty taste than others. The exact length of time must be determined by experiment. After rinsing off the fish in fresh water, they are placed on hangers or wire-mesh-bottom trays which are set outside in a cool, shady, breezy place to dry for about 3 hours before hanging in the smokehouse, at least 6 feet above the fire.

For the first 8 hours that the mackerel are in the smokehouse, they are cured in a dense cloud of smoke at as low a temperature as possible, not more than 90° F. The fire is then built up until the temperature is between 130° and 150° F., with less smoke. The fish are cured at this temperature for about 2 hours, or until the flesh has a glossy light brown color, partially cooking or hot-smoking the mackerel. The fish are allowed to cool before handling. Any moisture on the surface is then wiped off, the fish are packed in waxed or vegetable parchment paper and are ready for use. Unless held in refrigeration the period of preservation is brief, averaging about 10 days. With storage at 40° F. or less, smoked mackerel can be kept for an average of 60 days.

In some cases the mackerel are brushed over lightly with vegetable oil, usually cottonseed, either just after finishing the cold smoking part of the process, or on taking them out to cool after smoking. Another method of handling this fish after smoking is to cut the flesh into fingers the length of a No. 2 can or pint jar. After skinning, these pieces are packed asparagus-style into the container. Vegetable oil is then added until the spaces between the pieces of fish are filled and there is a layer of oil up to within a quarter-inch of the top. The containers are sealed and stored in a cool place until used. As this product is not sterilized it will not keep indefinitely and must not be held at room temperature.

Mackerel

Mackerel (*Scomber scombrus*), also known as Atlantic or Boston mackerel, is smoked in the vicinity of Boston and New York. Figures on production are not available as this item is included under miscellaneous smoked products in U. S. fishery statistics. It is estimated that about 30,000 pounds of mackerel are smoked annually. A small amount of smoked mackerel is canned. Most of the mackerel are caught by purse seines, though some is taken by pound nets, floating traps, and miscellaneous types of gear.

The method generally used in smoking mackerel is much the same as for kippered herring. The mackerel must be fresh and firm. "Belly-blown" fish do not make a good product. The mackerel are delivered from the wharf to dressing tables where the fish are split down the left side of the backbone from the tip of the head almost to the tail, or as for salting, and opened to lay flat in one piece. Gills, viscera, blood, and membranes are cleaned away. The fish are washed well, then soaked in fresh water from 15 to 30 minutes to remove diffused blood from the flesh. After draining a few minutes the mackerel are brined for about an hour in a brine testing about 80° salinometer. The proportion of brine to fish is usually two to one.

When sufficiently brined, the fish are fixed on smokesticks of the same type used for kippered herring. The heads are impaled on nail points on each side of the stick, with no two fish touching. The mackerel are allowed to dry for several hours until moisture is not apparent on the surface. Fans or blowers may be used for drying. The sticks of mackerel are then hung at least 8 feet above the fire and smoked for about 8 hours in a light cool smoke. The temperature should be less than

80° F. The fire is usually of hardwood chips, built on the two long sides of the smokehouse with an empty space in the middle. The ventilators may be left partly open as a dense smoke is not desired. When the smoked mackerel are cool, the individual fish are wrapped in vegetable parchment paper and packed in light wooden boxes holding about 10 pounds.

The process described by Stevenson (1899) is still used occasionally in New York. The fresh mackerel are washed, but not dressed, being brined in the round. They are left in a 90° salinometer brine for 12 to 14 hours, then removed and opened at the vent with the point of a knife to drain out the brine in the belly cavity. The mackerel are next fixed on smokesticks, with the stick inserted through the left gill cavity and out of the mouth. After draining and drying for 2 or 3 hours they are hung in the smokehouse, where they are given a cool smoke for 4 or 5 hours until properly colored. Then the fires are built up to a temperature between 150° and 200° F. and the fish are given a hot smoke for from 1 to 2 hours.

The Fish and Wildlife Service has made a study of the preparation of smoked mackerel (Stansby and Griffiths 1943) and has devised a method for curing smoked mackerel of better quality than that usually found in the market. The method is briefly as follows: The mackerel are dressed, removing the heads, and splitting down the backbone to lay open in one piece. Viscera, black skin, and other offal are cleaned out of the body cavity. The dressed fish are soaked in fresh water for 30 minutes to remove diffused blood from the flesh. They are then brined for 15 minutes in a 10 percent (38.5° salinometer) salt solution, used in the proportion of 2 pounds of brine to 1 pound of dressed fish. After brining, the fish are hung overnight in the smokehouse in a current of air created by means of a blower. This forms a thin film or pellicle on the flesh, resulting in a smooth, glossy surface, which absorbs and is colored uniformly by the smoke.

For a more rapid cure, forced drying may be used. The fish are drained for a short time, then hung in the smokehouse, which is heated to 100° F. and a current of air is drawn through the house by means of a blower. Drying is completed in about 4 hours.

A smokehouse in which temperature, humidity, and smoke density may be controlled, is used in smoking this product (Lemon 1932). The fish are smoked at a temperature of 100° F. and at as low a relative humidity as possible. Air-dried oak sawdust is used to produce a smoke of moderate density. Best results are secured by cold-smoking for 3 to 4 hours. The smoked mackerel then has a mild smoke flavor which does not hide the natural flavor of the fish. If a strong smoke flavor is desired the mackerel may be cold-smoked for 8 hours.

Mullet

The striped mullet (*Mugil cephalus*) is smoked commercially in small quantities on both coasts of Florida and as a noncommercial article for home consumption in all of the South Atlantic and Gulf Coast States. The commercial production of smoked mullet amounts to about 35,000 pounds annually. Some data have been collected on noncommercial mullet smoking but they are incomplete and unsatisfactory. It is estimated that production of noncommercial smoked mullet amounts to about 70,000 pounds annually. The methods of catching and handling mullet have been outlined under the discussion of dry salt mullet.

There is no regularity of procedure in smoking mullet and the product is variable in quality. Some mullet is hot-smoked by the method given for smoking Spanish mackerel. The method described here is recommended as giving the best results.

The mullet are split along the back just above the backbone, almost to the tail, so they will lay flat in one piece. The belly portion is left solid. The backbone is left in. All traces of viscera, membranes, black skin, and blood are cleaned out, taking special care to remove the coagulated blood and the kidney. The head may or may not be removed, depending on individual preference of the smoker. It is often removed when smoking the larger mullet. The heads are hard, and are difficult to cut mackerel style and to clean of waste material. They have no edible material, but since the smoked fish sell by weight, some curers like to retain the heads, thus reducing the loss of weight in curing. If the head is cut off, the hard bony plate just below the gills should be allowed to remain as it will be needed to carry the weight when the fish are hung on rods for smoking. If the "collar bone" is cut off, the mullet may pull loose and drop from the sticks.

After splitting, cleaning, and washing, the mullet are dropped into a salt brine testing about 40° salinometer. The proportion should be about 1 part salt to 10 parts water. The fish are left in this brine for 30 minutes to soak out blood diffused through the flesh. At the end of this time they are taken from the brine, rinsed, and freed of remaining traces of blood or other offal. After draining for a few minutes the mullet are dropped in a shallow box, partly filled with packers fine salt, where they are dredged about in the salt. When the fish have acquired a coating they are picked up with as much salt as will cling to the body and packed in even layers in a tub or box.

The mullet are left in salt from 1 to 3 hours (occasionally up to 8 hours) depending on weather, size of the fish, fatness, and length of time for which preservation is desired. The exact length of time must be determined by the smoker according to varying local conditions. When the fish are taken out of salt they are rinsed in brine and all visible traces of salt or dirt are scrubbed off. The mullet are then laid on chicken-wire drying racks on legs 3 feet high, kept out of the direct rays of the sun but located where a good breeze can reach them. Wire drying racks are desirable so the fish can dry on both sides; if laid on boards one side will remain wet. Before being hung in the smokehouse the mullet are given an average of about 3 hours' drying, or until a thin film is formed on the surface. If hung shortly after being taken out of salt, with the surface still moist, the fish require longer smoking, do not color and dry so well, and the appearance of the surface is not so attractive.

The mullet may be placed in the smokehouse on wire-mesh trays which are much easier to handle than by hanging on sticks with rows of nail points, or on thin iron rods. In no case should any two fish touch as this obstructs the drying and coloring action of the smoke. If hung on iron rods, more fish may be smoked at one time and will be better smoked, with a clearer color. Pointed iron rods are run through the mullet just below the hard, bony plate at the neck, one rod on each side (fig. 31). Thus each fish hangs from two rods. From 12 to 14 fish can be hung on a set of 2 rods 3 feet long.

The fire is started an hour or two before the mullet are hung in the smokehouse. Almost any hardwood or nonresinous wood may be used for fuel. Pine or other pitchy woods give the mullet a bitter taste. In experimental work it was noted that while buttonwood and tupelo were satisfactory over a short curing period, they too gave mullet an unpleasant flavor if used for any length of time (Jarvis 1933).

Some woods used in the southern States for smoking mullet are scrub oak, live oak, hickory, sweet bay, river mangrove, palmetto roots, and coconut husks. Sweet bay is considered to give mullet the best flavor. The odor is also faintly aromatic. Orange wood also gives a particularly pleasing flavor and a more attractive color than some of the others. The fires should not give off too much smoke during the first 8 to 12 hours of the process; after that a dense cloud of smoke is built up for the balance of the cure. The temperature in the smokehouse should not be allowed to fluctuate. In experimental smoking of mullet a fire made from two short chunks of wood about 2 feet long and the thickness of a man's arm, was usually found to be sufficient. The standard test for temperature is to put the hand into the smokehouse. The air should not feel distinctly warm on the hand. The mullet are smoked for 20 to 24 hours if they are to be kept for about 10 days and from 3 to 5 days if it is wished to keep them for some time.

After the mullet are taken out of the smokehouse they are dried for an hour or two in the air, then a little fine salt is sprinkled on each fish. They are wrapped in paper, packed in wooden boxes, and stored in a dry cool place.

Good results have also been obtained in experimental smoking of mullet with a hot-smoked product. The method is identical with the foregoing one up to and including 8 hours' cure in a light cold smoke. A dense smoke is then built up with a temperature of 200° to 240° F., and the fish are hot smoked for 30 minutes, if small; up to 60 minutes for medium- or large-sized mullet. The hot-smoked mullet have only a short period of preservation, about 10 days at a maximum. They are sold principally at roadside stands for immediate consumption.

Sablefish

Barbecued sablefish (*Anoplopoma fimbria*), also known as kippered black cod, smoked black cod, and barbecued Alaska cod, are cured and used in a few localities on the Pacific coast; in the vicinity of Chicago and Milwaukee, in the Great Lakes district, and in New York and Philadelphia on the Atlantic coast. The sablefish has firm, white, flaky flesh, and a full, rich flavor which make a smoked product of excellent quality. Although smoked sablefish is pronounced delicious by epicures, it has not found favor with the general public except in a few local markets. Barbecued sablefish should be cured much more extensively. If progressive fish-curers would promote the production and marketing of smoked sablefish they would create a steady demand for a profitable article. The United States produced a total of 1,175,000 pounds of smoked or kippered sablefish in 1940.

The largest part of the sablefish catch is made by long lines, although with the expansion of trawling on the Pacific coast, increasing quantities are now being taken in otter trawls. Sablefish are taken incidental to the halibut catch, but as the halibut are more valuable and the boats are restricted to a certain number of trips, the fishermen bring in the higher priced fish, avoiding and at times even discarding the lower priced sablefish. The development of trawling may change this to some extent.

Sablefish or black cod are almost too fat to cure by cold smoking, although a small amount is prepared by that method. The rich, flaky flesh is much more suitable for hot smoking (kippering or barbecuing). Fresh or iced fish are sometimes used as raw material but as in kippering salmon, frozen fish are preferred, and for the same reasons. The flesh is firmer and therefore easier to prepare for smoking, and the curer is not dependent on a fluctuating seasonal catch but has an assured supply of raw material to be drawn on as required.

There is some variation in the method of handling. The sablefish are received by the smoker frozen, headless, and gutted. The frozen sablefish are first thawed in a tank of cold water. The fish are left in the tank overnight or for an average of about 12 hours. Some smokers use running water as it reduces the time required for thawing and because they have found that in a tank of still water the fish would freeze together in a mass unless stirred vigorously from time to time. The sablefish are cleaned and dressed while still partly frozen. The body may or may not be scaled, the fins are removed and the belly cavity is cleaned out. The fish are then split into sides. The splitter first makes a short cut just under the backbone and above the anal fin, in the region of the vent. A second short cut is then made at the same place, just above the backbone. A short preliminary cut is made just above the end of the backbone which can then be removed with another stroke of the splitting knife. The thin, belly flesh on each side is trimmed away. The belly trimmings may be smoked as strips or salted in barrels. The trimmed sides are cut into chunks which will weigh approximately 1 pound each after smoking. Pacific coast smokers of sablefish now often split sablefish in two sides and cut them in chunks without removing the backbone. This is guess work, of course, but experience brings remarkable accuracy. The average piece is approximately 6 by 3 inches.

The pieces of sablefish are placed in a tank to cure in a 90° salinometer brine for 2½ to 3 hours; the general rule being to brine this fish one-half hour longer than salmon under the same conditions. After brining, the fish are drained 5 to 10 minutes to remove surplus moisture. On the Pacific coast, the chunks are placed in wire baskets which are dipped for a minute into a tank of coloring solution. The dye used is generally 150 Orange I, one of the analine food colors permitted under the Food, Drug, and Cosmetic Act. Other permissible dyes of the same group may be used. The undyed smoked product has a rather pale, unattractive color. The dye solution should be a little weaker than that used for salmon. The dye does not penetrate, is harmless and improves the appearance of the product. Sablefish smoked in the Middle West and Eastern States are not dyed, as the laws in most States in these areas prohibit the artificial coloring of food products.

After dyeing, the pieces of sablefish are placed, skin side down, in shallow trays with wire-mesh bottoms and wooden sides. The tray bottoms are previously coated with an edible oil to prevent the fish from sticking. No two pieces should touch each other. In some plants the trays are stacked on wheeled racks, which are later moved into the smokehouse. In other curing plants the fish are taken directly to fixed racks in the smokehouse. The trays are allowed to drip and drain for a few hours before the smokehouse fire is started, which is usually late in the afternoon. In some instances the sablefish are cured over a low fire, without much smoke, where they are dried and lightly smoked at a temperature around 70° F., for 14 to 16 hours. At the end of this period, the fire is built up sufficiently to partially cook the fish, at a temperature around 250° F., for 25 to 30 minutes. Other curers smoke the fish at temperatures varying from 70° to 100° F. for the first 8 to 10 hours. The temperature is then raised to 150° to 170° F. where it is held about two hours for the "cooking."

The barbecued sablefish are then cooled. Some plants use fans to shorten the cooling period. The individual chunks are wrapped in oiled paper, cellophane, or parchment. Sometimes the brand name and other information is printed on the wrapper. In other instances a printed tab is fixed directly to the piece of fish, which is then covered with a plain wrapper. The wrapped pieces are packed in light wooden boxes lined with oiled paper, holding 10 pounds, or in special moisture-proof and oil-resistant heavy fiber boxes containing 10, 20, or 30 pounds of fish.

Barbecued sablefish is a perishable product which spoils after a few days at room temperature, and only quantities that may be readily disposed of are ordered by retail dealers. If the sablefish is to be kept longer than a few days, it should be held in storage at temperatures below freezing. The retailer should hold it in a refrigerated show case at not more than 40° F. Barbecued sablefish is best liked when served steamed or broiled with a parsley butter sauce. As it is somewhat like kippered salmon, it should make good sandwiches and salads.

Sturgeon

Three species of sturgeon are smoked in the United States. The common sturgeon (*Acipenser oxyrhynchus*) is found along the Atlantic coast from Maine to South Carolina but is now taken principally in New Jersey and Virginia. Large-mesh gill nets were formerly used in fishing but most of the catch is now taken in pound nets, incidental to other fisheries. This species has been greatly depleted through overfishing and water pollution.

The green sturgeon (*Acipenser acutirostris*) is distributed from northern California to Alaska, but the commercial catch is now almost entirely taken in the Columbia River area. Small sturgeon are taken in salmon gill nets but the large ones are only caught by the use of set lines specially made of strong rope, and with a large iron hook. The green sturgeon may attain large size. It is reported that the record weight is 1,000 pounds, with a length of 13 feet.

The third species smoked in the United States is known as the Caspian sturgeon (*Huso huso*) imported frozen from the U. S. S. R. Caspian sturgeon may include other species such as *Acipenser mediventris* and *Acipenser ruthenus*, as the common name apparently is used rather loosely for several species. Some fresh and frozen sturgeon is also imported from Canada.

Nearly all the sturgeon used in this country is smoked before going into the markets. Despite the fact that it is a very high priced product, probably the highest on the market, smoked sturgeon is in great demand. The annual production varies between 1,000,000 and 2,000,000 pounds, depending largely on the availability of imported sturgeon. Very little smoked sturgeon is imported. Production at one time was much higher, amounting to 4,000,000 pounds annually, according to Stevenson (1899). Domestic sturgeon was then abundant and the price was much lower, or about 25¢ per pound wholesale, whereas the price is now $1.50 or more.

During the nineteenth century sturgeon for smoking was brine salted very much like hard-cure salmon and held in barrels until required, when the salt was soaked out in fresh water, as in smoking salmon. This method is no longer used. Fresh fish are used as soon as they reach the plant. Frozen fish, mostly imported, are held in the freezer until required for smoking.

Fresh sturgeon are cut in chunks of about 2 pounds each. The skin is usually left on. These pieces are brined for 10 to 12 hours in a 90° to 95° salinometer brine. On removal from cold storage, frozen sturgeon are thawed in a tank of cold water. The time required until the fish can be handled is about 12 hours. They are then treated exactly like fresh sturgeon. Some smokers roll fish in dry salt, with or without spices crushed in the salt. Others use crushed bay leaves, black peppers, and cardamom seeds. The fish are then packed in a salting butt, with just enough 90° salinometer brine poured in to cover. Some curers prefer a light brine cure, not over 30 minutes. Dry salting is preferred by some curers, who report that it makes the flesh harder and firmer.

After salting, the pieces of sturgeon are rinsed in fresh water to remove excess salt, dirt, slime, or other debris. Sturgeon given a short brining is not rinsed. The chunks of sturgeon are then placed on wire-bottom trays, previously oiled to prevent sticking. No two pieces should touch. The surface moisture on the sturgeon is usually allowed to dry off before the trays are placed on racks in the smokehouse. This may be done by a fan. Some smokers still use the old method of stringing the pieces on iron rods, 8 or 10 chunks to the rod, the rod passing through the thin part of the chunk. The rods are then hung in the smokehouse. The trays or rods are fixed from 4 to 6 feet above the smokehouse floor. A low fire is then lighted on the floor and the sturgeon are cured in a light smoke, with all smokehouse ventilators open, for an average of 4 hours. The time is varied according to the weather, and the flavor and texture preferred by the local market. The time must be much longer when the weather is sultry. The minimum time can be used when the weather is breezy and cool. After this period of light smoking, doors and ventilators are closed, a hot fire is built up and the fish is smoked and partly cooked from 1 to 2 hours at a temperature around 175° F.

A few smokers cure the fish for 7 or 8 hours in a rather dense smoke at an even temperature around 125° F. It is reported that 100 pounds of dressed sturgeon will yield 63 to 70 pounds smoked product. Smoked sturgeon are subject to mold if held in chill storage. Some smoked or kippered sturgeon is canned (Jarvis 1944a).

Whitefish, Lake Herring, and Lake Trout

The smoking of lake herring is centered in the Great Lakes area and the smoked product comprises the major production of the fish-smoking industry in the interior region of the United States. The same method is used in smoking lake herring, whitefish, and lake trout. Some lake trout are smoked like salmon. Unscrupulous retailers sometimes attempt to sell lake herring as the more expensive and desirable whitefish, as the finished product is somewhat similar (Tariff Commission 1927). Most of the lake herring and whitefish are imported as frozen fish from Canada. The fish are held in cold storage and are withdrawn as required for smoking.

The frozen fish are first thawed in a tank of cold water. The temperature of the water should be only slightly above the freezing point. Some smokers leave the fish in tanks overnight without changing the water. Others thaw the fish in running water for about four hours. The fish are removed before they are completely thawed as they are firmer and easier to handle. After thawing, the fish are split down the belly to the vent and are eviscerated. The dressed fish are washed thoroughly, taking especial care to remove all traces of blood near the backbone.

After washing, the fish are allowed to drain for a few minutes and are then packed in layers in a brining vat. Some smokers use rectangular vats about 4 feet in width, 10 feet long, and 3 feet deep; others use hogsheads. A small quantity of salt, from 5 to 10 pounds per 100 pounds of fish, is scattered among the fish as they are packed in the vat. The vat is then filled with brine testing 90° salinometer. Sometimes the fish are packed in dry salt, without brine (Jarvis 1945b). Sufficient salt to cover the fish is scattered over each layer. The fish may be taken out of the salt after periods varying from 3 to 10 hours, depending on the flavor desired, the season, and the length of time for which preservation is desired. The salt method is usually followed in summer. Sometimes in winter the fish are cured in brine without the addition of salt. The fish are taken out of brine after a period of from 10 to 16 hours, varying with the preference of the trade, season of year, and amount of fish in the salting vat.

After draining for a few minutes, the fish are hung for smoking. One method is to pass a round smokestick through the right gill and out of the mouth. In some establishments the stick is passed through the eye sockets of the fish; in others, an iron wire curved **S**-shape is used to attach the fish to the stick, one end of the wire passing through the fish at the head or beneath the nape bone, and the other being hung over the smokestick. Some smokehouses use sticks about 2 inches thick and 3 inches wide. Nails are driven through the sticks so that the points project at an angle on each side at 3- or 4-inch intervals. The fish are impaled on these points either under the nape bones or through the vertebrae near the tail.

The method described by Stevenson (1899) is also used:

> The fish are secured by having stout smokesticks, about 1½ inches thick and 2½ inches wide, in the top of each, and about ¼ inch from the edge is driven a row of tacks or small wire nails at intervals of about 3 inches, projecting about ½ inch above the surface. Ordinary cotton wrapping cord is tied to the wire nail at the end of each stick, the fish being placed with the back of the neck against the stick and the cord passing from one nail around the throat of the fish entering under the gills on each side, and then around the next nail, and so on to the end. By having the stick of sufficient width a row of such nails may be placed on each edge, so as to attach a row of fish at each side. This removes nearly all the risk of the fish falling and their appearance is not marred by holes through which the smokestick has passed.

When the lake herring or whitefish are all hung, the loaded sticks are dipped in fresh water to remove any brine or excess salt from the surface of the fish. The sticks are then hung in a current of air until no moisture is apparent on the surface of the fish. Large mechanical fans are used for this drying operation by some smokers. The sticks are then hung in the smokehouse at 6 to 8 feet from the ground. The smokehouse is of the ordinary type used in smoking other fishery products and has no special features. Any hardwood may be used for fuel. Hardwood sawdust and chips from woodworking plants are commonly used.

The fish are cured over a light smoke with the smokehouse dampers open for 5 or 6 hours. The temperature at this time should not be more than 90° F., preferably 80° F. At the end of this time the fires are built up, the smokehouse dampers are closed, and the fish are cooked in a dense smoke at 170° to 180° F. for 1 to 2 hours, depending on the height at which the fish are hung, size of the fish, and type of cure demanded in the locality. The fish are allowed to cool, and are then packed in parchment or wax-paper lined wooden boxes for distribution to retailers. The loss of weight in cleaning and smoking averages 50 percent. The product will keep about 10 days.

For sale in markets which prefer the herring well smoked on the inside, the belly cavity is held open by means of toothpicks or somewhat thicker small wooden sticks, two sticks to each fish. This allows the smoke to strike into the belly cavity more completely and gives a product that will keep longer. In general, the western trade prefers the stomach cavity open; the eastern trade does not.

Shrimp

Smoked shrimp is a product which has been prepared commercially only within the past few years. So far as can be determined, it was not sold before 1940. Experimental work in the development of this product was done by the Fish and Wildlife Service, which issued information on two methods, and suggested to fishery interests in the southern States that smoked shrimp had possibilities as a specialty product.

The first method is as follows: Green, headless shrimp are peeled, then washed thoroughly. After draining for a few minutes, the shrimp, in 25 pound lots, are blanched for 5 to 8 minutes in a tank of boiling 50° salinometer brine. If the shrimp are small, the shorter blanching is given; if the weather is humid, the longer time is used. Length of blanching also depends to some extent on market preference. The blanched shrimp are dried, either in the air or by a blower fan, then spread in a thin layer on wire-mesh-bottomed trays previously oiled to prevent sticking. If possible, the meats should not touch each other. The trays are placed on racks in a smokehouse and cured in a dense, cool smoke (temperature not more than 80° F.) for approximately 90 minutes. If a lightly smoked shrimp is desired, 1 hour should be sufficient. The peeled shrimp may be packed in glass tumblers, vacuum sealed, either dry or with vegetable oil. They may also be packaged in glassine or cellophane envelopes holding about 2 ounces.

According to the second method, the shrimp are smoked in the shell (Young 1945). The whole shrimp are first headed, then washed thoroughly in cold running water to remove weeds, dirt, or other extraneous matter. After draining a few minutes the shrimp are placed in a 50° salinometer brine to soak for from 30 to 60 minutes. Length of brining and strength of brine depend on local market preference; some people like a salty shrimp, others prefer a mild flavor. The shrimp are then steamed or boiled until they turn pink, indicating that they are sufficiently cooked. The shrimp may also be boiled in a 50° salinometer brine eliminating the brine-soaking step.

The cooked shrimp are spread on wire-mesh-bottomed trays separated so that no two shrimp touch, then dried, either in the open or in the smokehouse, at room temperature (70° to 80° F.) until dry to the touch. A blower or electric fan reduces the drying time and results in a more evenly dried product. Air drying or natural drying may require 2 hours. Artificial drying takes from 10 to 30 minutes.

The shrimp are then cured in a dense cool smoke, preferably at a temperature between 70° and 90° F. Oak or hickory sawdust is preferred for smoking. Softwood sawdust used alone gives the shrimp a bitter taste. A dense smoke is recommended because the smoking time is shorter and the shrimp do not dry out so much. The smoking time varies between 60 and 90 minutes, depending on the size of the shrimp and whether a light or heavy smoke cure is desired. Lightly smoked shrimp in the shell should have a light reddish-brown color. The meat is sweet in flavor with just a tang of smoke. Smoked shrimp in the shell is expected to become a popular cocktail relish. A yield of about 60 pounds of smoked shrimp should be obtained from 100 pounds of green, headless shrimp.

DELICATESSEN PRODUCTS

Delicatessen fishery products are classified as such in this handbook because they are largely retailed through food stores of this type. The basic ingredients of these products are salt and smoked fish. Preparation often involves the use of vinegar and spices. While they are not so stable as some types of cured fish, preparation in various ways keeps these products in good condition longer than ordinary fresh fish. More important, however, is the fact that these products are made more appetizing and palatable, thus appealing to consumers who would not relish greatly the ordinary types of cured fish. The recipes given here are only a few of the most popular kinds. There are many others. The products described here have been tested.

Herring Salad

Herring salad is a favorite method of preparing salt herring. There are a great many formulae for this dish. If heat-processed, in glass, a special type of mayonnaise with a much higher solid vegetable fat content is used. The unprocessed herring salad, if packaged and held at low temperatures (about 40° F.), will remain in good condition for several weeks, and is usually more appetizing than the processed type. This also applies to tuna salad. Sodium benzoate (1/10 of 1 percent) may be used as a preservative, if presence and amount are stated on the label.

Herring Salad, Alaska

10 lb. salt herring
2 lb. pickled beans
1 lb. cucumber pickle, sour
1 lb. cucumber pickle, sweet
1 lb. mustard pickle
3 lb. apples
2 lb. mayonnaise
½ lb. smoked salmon
¼ lb. onion
1 bottle (2 oz.) capers

Soak the salt herring in water for about 24 hours, changing the water two or three times, or freshen in running water for 4 to 6 hours. Skin and fillet the herring, removing all bones. Dice into small pieces. Peel and dice the apples, keeping under water until needed, to prevent discoloration. Chop finely the sweet and sour cucumber pickles together with the mustard pickles, pickled beans, and capers. Dice the smoked salmon and grate the onion. Mix all ingredients thoroughly with the mayonnaise. The salad should stand at least 24 hours to blend flavors. This salad is usually served on lettuce with a garnish of sliced hard boiled eggs, capers and nut meats.

Herring Salad, German

25 lb. potatoes, boiled
28 lb. cucumbers, salted
20 lb. beets, boiled
50 lb. herring, salt
10 lb. mayonnaise
1½ lb. onions, ground
½ lb. horse-radish, ground
2 oz. pepper
3 lemons, juice and oil (optional)

Paprika to taste

Freshen herring by soaking in a tank of water from 11 to 24 hours, depending on individual taste. Then skin, fillet, and dice fish. Dice cucumbers, beets, and potatoes and mix with herring. Mix horseradish, onions, and pepper with mayonnaise. The juice and oil of 3 lemons may be added, if desired. Fold mayonnaise mixture lightly but thoroughly into the other ingredients. Package and store at 34° to 40° F.

Herring Salad, Italian

10 lb. boiled tongue
6 lb. apples
20 lb. boiled potatoes
6 lb. celery
10 lb. carrots
30 lb. salt cucumber
20 lb. salt herring
6 lb. mayonnaise
1½ lb. ground onions
½ lb. horse-radish

Curry powder, mace, and pepper to taste.
Juice and oil of 3 lemons optional.

Freshen the salt herring by soaking in water overnight. Skin and fillet, removing all bones. Dice. Chop the celery fine. Peel apples, potatoes, and carrots and cut into small dice. Dice tongue and cucumbers. Mix all these ingredients thoroughly. Blend onions, horseradish, and spices with the mayonnaise. The juice and oil of 3 lemons may also be added, if desired. Then add mayonnaise to other ingredients. Store in a cool place. Though this herring salad is known as Italian it was obtained from a German source.

Herring Salad, Swedish

5 lb. salt herring
3 lb. boiled veal
½ lb. ham
2 lb. boiled potatoes
2 lb. boiled beets
2 lb. apples
½ lb. onions
½ lb. sour pickles
2 lb. French dressing
1 pt. white vinegar
½ lb. chopped anchovy fillets

Soak herring in fresh water overnight (12 hours). Skin and fillet, removing all bones. Wash and drain, then cut into small cubes. Mix with chopped veal, ham, anchovies, onions, diced potatoes, beets, apples, and pickles. Add French dressing and vinegar. Mayonnaise may be substituted for French dressing, or the French dressing may be diluted with mayonnaise. Stir thoroughly together and store in a cool place for 48 hours. Arrange on platter and garnish with sliced hard boiled eggs, capers, small pickled onions, parsley, and mayonnaise.

Smoked Herring Salad

8 oz. canned smoked herring fillets in oil
4 oz. anchovy fillets
2 lb. boiled potatoes
2 lb boiled beets
2 lb. tart cooking apples
½ cup finely chopped onion
¼ cup vinegar
4 tbs. sugar
1½ cups whipping cream

Cut herring and anchovy fillets into very small cubes. Peel boiled beets and potatoes, then cut into larger cubes. Peel apples and cut into the smallest possible cubes. Apples are intended to give freshness to the taste, but should not be visible. Mix fish, beets, potatoes, apples, and onion. Add vinegar in which sugar has been dissolved. Ingredients should be mixed very lightly so that the cubes are not broken. Finally fold in the cream whipped to the consistency of a thick sauce. It must not be too thick or it will curdle when mixed. Pack in containers, to be sealed and held at a temperature of 40° F. until retailed.

Tuna Salad I

No two commercial tuna salads are prepared by exactly the same formula, but they do not show the wide variety characteristic of herring salad. The recipe given here is typical. It is offered, however, only as a guide. The same recipe with minor variations to suit the taste may be used for salmon salad.

5 lb. tuna
2½ pt. finely diced celery
1 pt. finely diced sweet pickle
12 diced hard boiled eggs
1½ pt. mayonnaise
½ lb. hydrogenated vegetable shortening
1½ tsp. salt
¾ tsp. pepper
5 lemons

Flake tuna, dice celery, pickles, and eggs. Extract juice of lemons. Combine all ingredients except lemon juice. Season with salt and pepper, and sprinkle lemon juice over the whole. Combine shortening with mayonnaise, then mix with other ingredients. In some formulae one pint of diced cucumber is included. Others use sour instead of sweet pickles. Still others use capers in place of pickles. These variations are entirely a matter of taste. Package and hold at 40° F. until retailed.

Tuna Salad II

This is the only commercial recipe for tuna salad that differs widely from the one given above.

5 lb. tuna
5 lb. diced boiled potatoes
2½ cups diced dill pickles
7½ cups French dressing

Salt and cayenne to taste.

Flake tuna, mix with other ingredients and season. Fill the salad into containers and hold at 40° F. until retailed.

Salmon Salad

5 lb. salmon
5 lb. diced boiled potatoes
2 cups diced onion
8 cups sour-cream dressing

Salt, pepper, and fresh dill to taste.

Combine ingredients, then season with salt, pepper, and dill, mixed. A cup of diced dill pickle is sometimes used in place of fresh dill. Sometimes a half cup of fresh grated horseradish is added to the sour-cream dressing, omitting fresh dill or dill pickles. To make this amount of sour-cream dressing take:

6 cups sour cream
6 eggs beaten lightly
1 cup vinegar
4 tbs. salt
2 tbs. mustard
¾ tsp. pepper

Add eggs, vinegar, and dry ingredients to cream, mixing thoroughly. Cook dressing in a double boiler stirring constantly, until the mixture begins to thicken. Package and store like herring or tuna salad.

Fish Cakes

Fried fish cakes are sold rather widely in delicatessens and at prepared food counters of department stores in the Atlantic coastal area. This product has possibilities for other sections of the country.

10 lb. potatoes
5 lb. shredded salt cod
8 lb. eggs, beaten
8 oz. butter or margarine
1 lb. diced onions
¼ oz. pepper

Soak fish in cold water for several hours. Then shred or break into small pieces. Place fish in a kettle and add water. Heat to boiling point, and drain off water. Boil potatoes and fish together until done. Drain off liquid and put fish and potatoes in meat grinder with

¼-inch plate. Put ground mass in an electric mixer, add beaten egg, margarine, onion, and pepper and beat until ingredients are thoroughly mixed. Onions are not used unless the trade has a preference for them. Form mixture into cakes of the usual size, dip in beaten egg, roll in fine bread crumbs, and fry until a light brown. The cakes are not packaged but sold from refrigerated display cases held at approximately 40° F.

Crab Cakes

Crab cakes are sold rather extensively in delicatessens and food stores in Maryland, Virginia, and North Carolina, and also to some extent in other Middle Atlantic and Southern States. The product varies widely in quality, usually according to the quality of ingredients, cooking fat, and care in preparation. Any good standard recipe is satisfactory. The following formula is recommended:

5 lb. crab meat
2½ cups soft bread crumbs
⅔ cup minced onion
6 oz. butter
5 beaten eggs
2 tbs. dry mustard
2 tbs. Worcestershire sauce
Salt, paprika to taste

Melt butter, add onion, and cook until soft and yellow. Add other ingredients and mix together. If the texture is too dry add small amount of milk. Form mixture into cakes of the desired size (usually about the same as cod fish cakes), dip in beaten egg, roll in bread crumbs, and fry in deep fat (about 375° F.) until brown. Drain cakes on fat-absorbent paper. Handled like fish cakes.

Seviche

Seviche is typically a South American preparation. It is sold commercially in the United States principally in the Latin-American quarters of our large cities. It is essentially cubed raw fish, preserved by marinating in sour-orange juice. This is not the juice of unripe oranges but a special variety of fruit with a very sour juice, which is grown in southern Florida. Lime juice is generally used as a substitute in the United States but in South America it is considered inferior to sour-orange juice. Lemon juice is never used. The fish should be fresh and firm fleshed. Corvina is most favored in South America. Striped bass has been found to be the best substitute in North America, though sea trout (weakfish) may also be used. The ingredients are:

10 lb. fish
5 large onions
3 cloves of garlic
5 cups lime juice
12 to 15 yellow chili peppers
Salt and cayenne to taste

Scale fish and clean thoroughly. Fillet fish, removing backbone and cut fillets into half-inch cubes. Wash and drain diced fish. Slice onions thin, then mix with garlic, ground fine. Mix fish and onion-garlic mixture together in a large bowl and season with salt to taste. Slice peppers and add. The yellow hot peppers of Louisiana, preserved in glass, are acceptable for the purpose. Stir a little cayenne pepper into lime juice and pour over the whole. Tartaric acid, dissolved in water, is sometimes used instead of lime juice. The seviche is allowed to stand overnight before use. This preparation will remain in good condition about 5 days at average room temperatures, and longer under refrigeration.

Seviche is also made from shellfish such as clams or mussels and shrimp or fresh-water crayfish. The general method of preparation is as described above. The meat of the crustacea is used raw or "green." The clams and mussels are shucked raw. Only the "beard" is removed from the mussels. The dark body mass or "stomach" is separated from the clams.

Gravlax (Marinated Salmon)

10 lb. salmon
1 pt. olive oil
1 cup salt
1 cup brown sugar
¼ cup fresh, chopped dill
1 tbs. allspice
1 tbs. white pepper
1 tbs. saltpeter
1 tsp. mace

This is a favorite Swedish delicatessen dish. Clean and wash the salmon, thoroughly. Then split lengthwise, removing the backbone. Rinse fillets, drain and wipe dry. Rub oil well into both sides of the fish halves. Mix together salt, sugar, saltpeter, white pepper, ground allspice, and mace. Coat both sides well with mixture, rubbing into flesh. Place chopped dill on top. Place both halves together and tie tightly with string. Set in a shallow pan and press under moderate weight for 48 hours. Serve in thin slices. May be packaged in glass. Store at 34° to 40° F.

Lutefisk

Lutefisk is a food product of Scandinavian origin, prepared from stockfish. Lutefisk is prepared by a special process. Stockfish is a split, dried, unsalted codfish (see section on curing stockfish). Hard-dried or export-cure salt cod is sometimes used in making lutefisk, but is considered inferior to stockfish as raw material.

Lutefisk is sold at most of the better groceries and delicatessens in the Middle West and at some delicatessen shops in the eastern United States. The large importers and dealers in fancy food stuffs in Chicago and New York City always have an abundance of lutefisk at the Christmas season, for it is a favorite dish at Christmas and New Year among all Scandinavian people.

To prepare lutefisk for this trade, proceed as follows: Cover the stockfish with clear cold water and allow it to soak for 4 days, being sure to change the water every day. The fish should be kept in a cool place preferably out-of-doors as the odor is objectionable to some people, but care should be taken to prevent freezing as this ruins the product. When the fish has been sufficiently soaked, cover with cold water to which has been added a solution of soda and lime; for 5 pounds of fish use 2 cups of washing soda and 3 or 4 cups of slack lime to about 12 gallons of water. A large container such as a salting butt is used for soaking. Let the fish soak in this "lute" for 3 or 4 days. Pour off the solution and again soak the fish in clear cold water for at least 3 days to remove all of the chemicals, changing the water every day. Keep in a cool place or the fish will spoil. The lutefisk should now have the desired consistency and flavor.

If directions for cooking are requested the standard recipe is: Cover fish with cold water and allow it to come to a boil, adding a little salt. Boil about 10 minutes, then pour off water. The cooked lutefisk should have a white and flaky appearance, breaking into pieces as it is placed on a platter. Serve with melted butter or a white sauce, together with boiled or mashed potatoes, dashed with pepper and salt to taste.

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INDEX

Page

- Abalone
  - drying 24
  - gathering 23
- Air-dried fishery products 15
- Alewives
  - caviar 184
  - salting 100
    - catching, handling, landing 100
    - corned 103
    - inspection and grading 103
    - packing 102
    - washing and butchering 101
  - smoking 232
  - spicing and pickling 149
- Anchovies
  - appetitsild 157
  - formulas
    - German 157
    - Scandinavian 156
    - Spanish 80
- Angler fish. (See *Goosefish.*)
- Animal life, spoilage in fish curing 76
- Autolysis, action in spoilage 12
- Bacteria 11
- Bait. (See *Salmon, eggs.*)
- Balyk 22
- Barracuda
  - dry salted 81
- Bass, Striped (Rock)
  - Seviche 257
  - smoked 233
- Beché-de-mer. (See *Trepang.*)
- Black cod. (See *Sablefish.*)
- Bloaters
  - American 205
  - English 206
- Bluefish
  - smoked 233
- Brine salting, in general 99
- Buckling 211
- Butterfish 233
- Calcium, effect of in salt for fish curing 40
- Canada
  - fish curing industry 8
- Carp
  - smoked 235

Page

- Catfish
  - smoked 236
- Caviar
  - cod 174
  - miscellaneous 184
  - mullet roe 177
    - dry salted 177
    - air dried and pressed 178
  - salmon 178
    - United States 178
    - U. S. S. R 179
  - sturgeon 164
    - industry 164
      - American 165
      - Russian 168
        - method of catch 169
        - pasteurized grain 174
        - preparation, grain in barrels 172
        - pressed 173
- Clams
  - drying 24
  - smoking 24
- Cod
  - brine packed 104
    - butchering and salting 104
    - repacking 104
    - pickled cod, European method 105
    - tongues 107
  - dry-salted 44
    - Atlantic coast industry
      - butchering and splitting 47
      - drying 51
        - air drying 52
        - artificial driers 54
      - foreign cures, methods
        - French 63
        - Icelandic 65
        - Norwegian 67
        - Scottish 69
      - general discussion 44
      - light cures
        - Gaspé cure 62
        - slack-salted cod and pollock 61

Cod—Continued Page
  dry salted—Continued
    Atlantic Coast industry—Continued
      packaging salt cod 56
        bricks 57
        hard-dry or export cod 60
        skinned and boned 56
        strips and middles 60
      salting 49
        kench cure 50
        pickle cure 50
      smoked. (See *Haddock*.)
      washing and cleaning 48
    Pacific cod industry 62
Cold-smoking of Fish 187
Corned herring. (See *Alewives*.)
Croakers
  smoked 233
Cusk
  salted. (See *Salt cod*.)
  smoked. (See *Haddock, smoked*.)
Cuttlefish. (See *Squid*.)
Dehydration of fish
  British Ministry of Food method 36
  Definition and principles 32
  Scott and Wolff 33
  U. S. Fish and Wildlife Service 34
Delicatessen products
  crab cakes 257
  fish cakes 256
  gravlax 257
  herring salad
    Alaska 254
    German 254
    Italian 255
    Smoked 255
    Swedish 255
  lutefisk 258
  salmon salad 250
  seviche 257
  tuna salad
    formulae 255
Eels
  Comacchio type 258
  pickled 161
  smoked 256
Escabeche 161
Finnan haddie
  American method 224
  Scottish method 225

Finnan haddie—Continued Page
  smoked fillets 230
  smokies 229
Fish curing
  Autolysis 12
  Canada, production 8
  Japan 8
  Optimum conditions for micro-organisms 11
  preservative action 10
  spoilage organisms
    bacteria 11
    molds 11
    yeasts 11
  statistical review of decline prospects 8
  United States, importance of fish curing in history
    Atlantic coast 2
    Pacific coast 4
Fish roe products. (See *Caviar*.)
Flounder 233
Gabelbissen 153
Gaffelbiter 153
Gravlax 258
Goosefish
  smoking 239
Grouper
  smoking 234
Haddock
  brine packed. (See *Cod, brine packed*.)
  dry-salted. (See *Cod, dry-salted*.)
  smoked 223
    American method, finnan haddie 224
    Scottish method, finnan haddie 225
    smoked fillets 230
    smokies (whole smoked) 229
Hake
  brine packed. (See *Cod*.)
  dry-salted. (See *Cod*.)
  smoked. (See *Haddock*.)
Halibut
  air-dried (rackling) 13
  smoked 239
Herring
  brine packed 118
    cures
      Alaska Scotch 124
      Dutch 129

Page

- Herring—Continued
  - cures—Continued
    - Matje 132
    - Norwegian 130
    - Round 120
    - Scotch 122
    - Split 121
    - United States
      - condition of raw material 125
      - curing 127
      - gibbing 125
      - packing 126
      - rousing 125
  - dry-salted 82
  - salad 254
  - smoking
    - bloaters
      - English method 206
    - buckling 211
      - modified cure 212
    - hard-smoked 200
    - kippered 207
    - lake herring. (See *Smoked whitefish.*)
    - red herring 204
    - sprats 212
  - spiced and pickled
    - bismarck herring 152
    - cut spiced 150
    - gaffebiter 153
    - gabelbissen 153
    - gewurzhering 154
    - matjeshering 154
    - potted 156
    - rollmops 151
    - Russian sardines 154
    - sour cream 158
    - wine sauce 158
- Hot smoking of fish 188
- Irish Moss. (See *Seaweed.*)
- Japan
  - cured fish production 8
- Jumping Mullet. (See *Mullet.*)
- Kingfish or king mackerel dry salting 86
- Kippered herring 207
- Kippered sablefish 247
- Kippered salmon 220
- Klipfisk 68
- Lakefish. (See *Lake herring.*)

Page

- Lake herring
  - salting 108
  - smoking 251
- Lake trout
  - smoking 251
- Ling cod 224
- Mackerel
  - brine packed 109
    - butchering 110
    - curing and repacking 113
    - fillets 114
    - method of catch 110
    - packing 112
    - production and imports 109
    - quality and grades 114
    - salt requirements 112
  - dry-salted
    - anchovy style 83
  - smoked 243
- Magnesium in salt, effect in fish curing 40
- Marinating. (See *Spiced and pickled fish.*)
- Matjeshering 154
- Mild-curing, salmon 133
- Mullet
  - brine salted 115
    - repacking and storage 116
    - salting 116
    - splitting, cleaning and washing 115
  - dry-salted 84
  - smoked 245
- Mullet roe
  - air-dried and pressed 177
  - dry-salted 177
- Mussels
  - air-dried 24
  - spiced or pickled 163
- Miscellaneous cured products
  - air-dried 22
  - brine packed 99
  - caviar 184
  - dry-salted 80
  - smoked 232
- Norway
  - salting
    - cod (klipfisk) 68
    - herring 130
  - smoking
    - salmon 217
  - stockfish 217

Page

- Octopus 24
  - air-dried 24
    - levantine 24
    - oriental 25
- Oysters
  - air-dried 24
  - spiced or pickled 162
- Philippine Islands
  - trepang 29
  - shark fins 16
- Pickled salmon. (See *Salmon, hard-salted.*)
- Pollock
  - dry-salted. (See *Cod.*)
  - smoked 230
- Quahaug. (See *Clams.*)
- Rackling. (See *Halibut.*)
- Ray
  - air-drying 15
- Red drum
  - dry-salting 87
- Reddening, salt fish 73
- River herring. (See *Alewife.*)
- Roe
  - cod 176
  - mullet 178
  - salmon 180
  - sturgeon 164
  - tuna 181
- Roll mops
- Russia
  - air-dried sturgeon 22
  - caviar 179
- Rusting, salt fish 42
- Sablefish
  - brine packed 117
  - kippered 247
  - smoked 247
- Salmon
  - air-dried 14
  - eggs for bait 180
  - hard-salted or pickled 142
    - bellies 145
    - butchering 143
    - grading and repacking 145
    - production 142
    - raw material requirements 143
    - salting 144
    - species 142
    - washing 144
  - mild-cure 133
    - butchering 134
    - general instructions 133

Page

- Salmon—Continued
  - mild-cure—Continued
    - repacking 140
    - salting and packing 137
    - storage 141
    - use of preservatives 141
    - washing, trimming, chilling 135
  - salad 256
  - smoking, methods 213
    - American 213
    - German 218
    - Indian cure 219
    - Kippered 220
    - Norwegian 217
    - Scotch 216
  - spiced 158
- Salting
  - principles 39
  - factors affecting salting of fish 39
  - preservative action of salt 39
    - osmosis 39
  - warm climates, method for 93
    - dressing and splitting 95
    - drying 96
    - handling raw material 94
    - location requirements 94
    - previous studies 93
    - species suitable 94
- Scotch cure, of herring 122
- Scottish method
  - cod 69
  - finnan haddie 225
  - kippered herring 208
  - salmon smoking 216
- Sea-herring. (See *Herring.*)
- Seaweed
  - dulse 31
  - Irish moss 32
- Seviche 257
- Shad
  - brine packed 99
  - smoked 233
- Shark
  - air-dried 15
  - dry-salted 91
  - fins 16
- Shrimp
  - air-dried 26
  - pickled 163
  - smoked 252
  - spiced 163

Page
Skate. (See *Shark, air-dried.*)
Smoking of fish
  chemistry 185
    liquid smoke and other preparations 186
    preservatives for smoked fish 187
  cold smoking 187
  development 185
  dressing or preparation for smoking 188
    drying 189
    salting 188
  hanging fish for smoking 197
  hot smoking 196
Smokehouses
  construction 189
    Canada 194
    Maine 190
    Middle West 192
    New York 191
    Northwest 192
    Washington State 196
  fuels 196
Smokies. (See *Haddock, smoked.*)
Spanish mackerel
  smoked 242
Spiced and pickled fish
  development 146
  ingredient requirements 148
  preservative action of ingredients 147

Page
Spoilage in cured fish
  bacterial spoilage 75
    dun cod 75
    molds 75
    reddening 75
  other types of spoilage 76
    animal life 76
    insect life 76
    enzymic changes 77
    physical and chemical deterioration 77
Sprat. (See *Herring, smoked.*)
Squid
  air-dried 25
Striped bass
  smoked 233
Sturgeon
  air-dried 21
  caviar 164
  smoked 249
  spiced or pickled 160
Trepang, drying 30
Tuna
  caviar 183
  dry-salted 92
  salad 255
United States
  fish curing industry 6
Veziga 21
Whitefish
  smoked 251

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